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ANALYSIS OF GOVERNMENT FACSIMILE EQUIPMENT AND NETWORKS

MAY 1991

OFFICE OF THE MANAGER
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Analysis of Government Facsimile Equipment and Networks

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Delta Information Systems, Inc.
Horsham Business Cneter, Bldg. 3 Suite 120
300 Welsh Road
Horsham, PA 19044-2273

National Communications System
Office of Technology & Standards
701 S. Court House Road
Arlington, VA 22204-2199

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The purpose of this task is to investigate strategic and tactical facsimile equipments and networks employed by the Federal government (including both those currently in the field and those due for deployment in the near future), determine their characteristics in terms of interoperability and compatibility, and, in those instances where incompatibilities are determined, to recommend how they might be made to interoperate. The Feeral government uses a wide range of facsimile equipment and networks ranging from commercial, off-the-shelf equipments designed for the office to special ruggedized equipment designed for the battlefield. In general, these equipment fall into two categories: strategic and tactical. Strategic equipments are used in office-like surroundings where the environment is usually well controlled, and operate over networks like the Public Switched Telephone Network (PTN) and the Defense Communications Network (DCN). Two examples of strategic equipments are off-the-shelf, commercially available facsimile equipments (Group 3, etc.) and commercially available equipments modified to communicate through encryption devices. Tactical equipments, on the other hand, ae used in harsh battlefield environments, operate over networks like the Mobile(See back)

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NCS TECHNICAL INFORMATION BULLETIN 90-19

ANALYSIS OF GOVERNMENT FACSIMILE EQUIPMENT AND NETWORKS

MAY 1991

PROJECT OFFICER

Stephen Perschau

STEPHEN PERSCHAU
Computer Scientist
Office of NCS Technology
and Standards

APPROVED FOR PUBLICATION:

Dennis Bodson

DENNIS BODSON
Assistant Manager
Office of NCS Technology
and Standards

FOREWORD

Among the responsibilities assigned to the Office of the Manager, National Communications System, is the management of the Federal Telecommunication Standards Program. Under this program, the NCS, with the assistance of the Federal Telecommunication Standards Committee identified, develops, and coordinates proposed Federal Standards which either contribute to the interoperability of functionally similar Federal telecommunication systems or to the achievement of a compatible and efficient interface between computer and telecommunication systems. In developing and coordinating these standards, a considerable amount of effort is expended in initiating and pursuing joint standards development efforts with appropriate technical committees of the International Organization for Standardization, and the International Telegraph and Telephone Consultative Committee of the International Telecommunication Union. This Technical Information Bulletin presents and overview of an effort which is contributing to the development of compatible Federal, national, and international standards in the area of facsimile. It has been prepared to inform interested Federal activities of the progress of these efforts. Any comments, inputs or statements of requirements which could assist in the advancement of this work are welcome and should be addressed to:

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National Communications System
ATTN: NCS-TS
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ANALYSIS OF
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DELTA INFORMATION SYSTEMS, INC
Horsham Business Center, Bldg. 3, Ste 120
300 Welsh Road
Horsham, PA 19044-2273
TEL: (215) 657-5270 FAX: (215) 657-5273

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1.0 INTRODUCTION

This document summarizes work performed by Delta Information Systems, Inc., for the Office of Technology and Standards of the National Communications System, an organization of the U. S. Government, under Task 3 of contract number DCA100-87-C-0078. The purpose of this Task is to investigate strategic and tactical facsimile equipments and networks employed by the Federal government (including both those currently in the field and those due for deployment in the near future), determine their characteristics in terms of interoperability and compatibility, and, in those instances where incompatibilities are determined, to recommend how they might be made to interoperate.

The Federal government uses a wide range of facsimile equipments and networks ranging from commercial, off-the-shelf equipments designed for the office to special ruggedized equipments designed for the battlefield. In general, these equipments fall into two categories: strategic and tactical. Strategic equipments are used in office-like surroundings where the environment is usually well controlled, and operate over networks like the Public Switched Telephone Network (PSTN) and the Defense Communications Network (DCN). Two examples of strategic equipments are off-the-shelf, commercially available facsimile equipments (Group 3, etc.), and commercially available equipments modified to communicate through encryption devices. Tactical equipments, on the other hand, are used in harsh battlefield environments, operate over networks like the Mobile Subscriber Equipment Network (MSE), and must be able to endure dirt, moisture, temperature extremes, shock, and vibration. Examples of tactical facsimile equipments are the Tactical Digital Facsimile AN/UXC-4 and the lightweight AN/UXC-7.

Besides their environment, the equipments belonging to these two categories differ in several ways. Some of which are listed below:

- Communication protocols
- Facsimile imagery (Black and white, gray scale)
- Compression techniques
- Transmission rates

- Encryption capability

Each phase of the study is discussed in the following sections. For example, section 2, "*FEDERAL GOVERNMENT FACSIMILE EQUIPMENTS*," describes strategic and tactical equipments used by the Federal government.

Section 3, "*CAPABILITIES AND CHARACTERISTICS*," describes the capabilities and characteristics of strategic and tactical networks and strategic and tactical facsimile equipments.

Section 4, "*COMPATIBILITY ANALYSIS*," compares strategic and tactical equipments, and discusses their interoperability.

Section 5, "*RECOMMENDATIONS*," recommends how equipments which are not interoperable could be made so.

2.0 FEDERAL GOVERNMENT FACSIMILE EQUIPMENTS

As mentioned before, the Federal government uses a wide range of facsimile equipments. These equipments are used to send facsimiles between the military, industrial concerns, contractors, and government agencies. Secondly, depending on the concern, the type of facsimile capability required varies. For example, the military requires gray scale facsimiles to be sent in a secure fashion (encrypted). They need to be able to transmit imagery, like photos or maps, to commanders in the field without revealing the imagery or the locations of the participating sites to the enemy. Whereas, government agency to industry facsimile transmissions are usually just black and white with no encryption (business letters, etc.). This section describes actual strategic and tactical equipments, and where and how they are used.

2.1 Tactical Facsimile Equipments

The military is the principal user of tactical facsimile equipment. They use tactical facsimile to transmit written orders, maps, photos, etc. over tactical transmission circuits from one battlefield post to another, from one centralized command post to another, or a mixture of ooth.

In general, these equipments must be rugged enough to endure harsh environments; they, like the soldiers using them, are exposed to the vigors of the battlefield and the fury of the weather. They must be able to endure extremes of temperature (freezing cold to broiling hot), too much or too little moisture, and shock and vibration. In addition, they must be portable, and must have low power consumption needs. Moreover, in this environment, these equipments must provide field commanders with high quality facsimiles quickly and securely. They must be quick to minimize revealing friendly positions to the enemy, and they must be secure to thwart enemy eavesdropping.

The military uses several types of tactical facsimile equipments. For example, the AN/GXC-7A Tactical Facsimile, manufactured by Magnavox Government and Industrial Electronics, Co., Torrance, CA, has been used by the U.S. Government since 1982. It features a carbon paper transfer method that can print on any type of paper, 8 shades of gray for

photographic imagery, and a 40 second transfer time for a typical tactical facsimile message (216 mm x 356 mm). In addition, it can be mounted on vehicles for mobile communications, or can be used in sheltered environments.

The AN/GXC-7B Tactical Facsimile, also manufactured by Magnavox Government and Industrial Electronics, Co., Torrance, CA, is an improved version of the AN/GXC-7A, and has been used by the U.S. Government since 1983. The AN/GXC-7B Tactical Facsimile provides both analog and digital facsimile transmission capabilities. The digital transmission capability allows the AN/GXC-7B to transmit over high speed communications channels (up to 32 Kilobits per second(Kbps)), and a typical tactical facsimile message can be transmitted in less than 28 seconds at 16 Kbps. Other features include three modes of transmission (non-compressed, compressed, and compressed with forward error correction), storage of a full page for transmission while simultaneously receiving a facsimile message, NATO (STANAG 5000) interoperability, and interoperability with most cryptographic equipment (including Tempest and the U. S. Tri-Tac system). The AN/GXC-7B is designed to be mounted on vehicles, or on ship or airborne platforms. Nevertheless, it can be easily removed for operation in sheltered environment.

The AN/UXC-4 Tactical Digital Facsimile, manufactured by Litton Systems, Inc., Amecom Division, College Park, MD, has been used by the U.S. Government since the early 1980's. The AN/UXC-4 is designed to give field commanders high quality pictorial and documentary information in near real-time. The AN/UXC-4's features include a laser on dry, electrophotographic paper transfer method that meets full tactical environment standards, 4, 8, or 16 shades of gray for photographic imagery, a less than 25 second transfer time for a typical tactical facsimile message at 9600 bits per second, four resolution modes, including 8 x 7.7 lines/mm, 8 x 3.85 lines/mm, 4 x 3.85 lines/mm, and automatic, where the resolution adjusts to image content accordingly, NATO (STANAG 5000) interoperability, selected data rates from 1.2 - 32 Kbits per second, full duplex operation, where imagery can be both transmitted and received simultaneously, and broadcast transmission capability, where an image can be transmitted to multiple receiving stations simultaneously. The digital operation of the AN/UXC-4 was designed primarily to operate within the U. S. Tri-Tac system, but the unit can operate with most cryptographic equipment (including Tempest and Tri-Tac). In addition, it is designed as a stationary unit for sheltered environments; but has a degree of portability - it can be carried by two men.

The AN/UXC-7 Lightweight Digital Facsimile, manufactured by Magnavox Advanced Products and Systems Co., Torrance, CA, has been used by the U.S. Government since 1989 as a part of the Mobile Subscriber Equipment (MSE) network. The AN/UXC-7 is an improved version of the AN/GXC-7A Tactical Facsimile. The AN/UXC-7 features include a carbon paper transfer method that can print on any type of paper, 8 shades of gray for photographic imagery, a message memory that allows for burst message transmission, transmitting a message (215 mm x 279 mm) in less than 15 seconds at 16 Kbits per second, three modes of transmission (non-compressed, compressed, and compressed with forward error correction), NATO (STANAG 5000) and MIL-STD-188 compatibility, both digital and analog transmission capability, and transmission rates between 75 bits per second and 32 Kbits per second. The digital operation of the AN/UXC-7 was designed to operate with both MIL-STD-188 and NATO equipment; the unit also operates with most cryptographic equipment (including STU-III and COMSEC). The AN/GXC-7B is a one-man portable equipment and can operate in any environment.

The TSF3800 Tactical Secure Facsimile, manufactured by 3M, St. Paul, MN, has been used by the U.S. Government since 1983. It's features include a thermal transfer method that meets full tactical environment standards, resolutions of 8 x 7.7 lines/mm and 8 x 3.85 lines/mm, NATO interoperability (Type I only), selected data rates from 0.6 - 32 Kbits per second, and digital operation. The digital operation of the TSF3800 was designed to operate with Type I NATO equipment, the unit also operates with most cryptographic equipment (including Tempest and Tri-Tac). In addition, the TSF3800 is a one-man portable equipment, and can operate in any environment.

2.2 Strategic Facsimile Equipments

Strategic facsimile equipments are used by both the military and government agencies. Since they are used primarily in the office, requirements for them are, in general, less stringent than those for tactical facsimile equipments. For instance, they do not have to be ruggedized, nor do they have to be portable, nor do they have to be able to simultaneously transmit to more than one receiver. Moreover, strategic facsimile equipments usually serve in a capacity similar to the role played by facsimile equipments found in the general public. In fact, a large number of the strategic equipments are the same brand equipments found in the public and private sectors.

Nevertheless, the Federal government does have some special requirements which the commercially available equipments are unable to fulfill. For example, the Federal government needs strategic facsimile equipments which transmit documents securely. Secondly, some of these equipments must be able to interoperate with tactical equipments. The strategic equipments the Federal government uses to fulfill these roles are, in general, modified, commercially available equipments; tactical facsimile equipments could be used, but their higher cost (because they are ruggedized) versus the lower cost of modified, commercially available machines make the commercial equipments more attractive. Two examples of secure strategic equipments are the Model 750T Secure Facsimile, manufactured by Ilex Systems Inc., Milpitas, CA, and the Model 750 non-Tempest version. In addition, non-secure, commercially available, off-the-shelf (strategic) equipments are available from a number of manufacturers. A few of these manufacturers are Sony, Panafax, and Ricoh.

3.0 CAPABILITIES AND CHARACTERISTICS

This section discusses tactical and strategic networks, and tactical and strategic facsimile equipments used by the U.S. Government.

3.1 Tactical Networks

The U.S. military operates a number of tactical networks such as the Extremely Low Frequency (ELF) communications system, the Fleet Satellite Communications System (FLTSATCOM), the Joint Tactical Information Distribution System (JTIDS), and the Tri-Tac Communications System.

3.1.1 Extremely Low Frequency (ELF) Communications Systems

The ELF communications system uses extremely low frequency (40-80 Hz) radio signals to communicate with submerged submarines. ELF was first proposed 30 years ago, but the extremely large antenna size and environmental worries prevented its use until recently.

ELF signals travel great distances with low loss and penetrate sea water to great depths. In practice, one or more shore-based transmitters use long horizontal and orthogonal wire antennas earthed at each end to send messages (One transmitter has 22.5 kilometer (km) long antennas, and orthogonal antennas are used to provide omni-directional radiation patterns). Once transmitted, submarines are able to receive these messages using towed antennas. Because the bandwidth is low at ELF, the message transmission rate is very slow; but by using simple three letter code systems, a great number of messages can be sent in a reasonable time.

3.1.2 Fleet Satellite Communications System (FLTSATCOM)

FLTSATCOM provides multi-channel UHF communications for the US Navy. It also supports US Air Force bombers and launch control centers, all airborne command posts, and some US Army nuclear capable force elements.

3.1.3 Joint Tactical Information Distribution System (JTIDS)

JTIDS is a US joint-service, jam-resistant, secure communications system, and allows the interchange of information between aircraft, surface vessels, mobile or fixed-base land stations, and command centers. It is a flexible, multiple-user tactical information exchange service, uses digital and voice links operating in the 960-1215 MHz band, and uses spread spectrum techniques to increase jam resistance.

User inputs automatically include identification and navigation data in addition to target acquisition details. Users may continuously monitor or sample the database for any information they may require. Nevertheless, recipients are usually unaware of the providers of the information; just as providers are usually unaware of the recipients.

3.1.4 Tri-Tac Joint Tactical Communications System

Tri-Tac is a hybrid system designed to allow a transition from analog systems to a fully digital and automatic system. In general, it combines both telephony and radio communications, and permits facsimile transmissions. Telephonic communications are, in general, provided by the mobile subscriber equipment (MSE); which is a corps-wide, common user telephone system which serves both stationary and mobile users.

3.2 Strategic Networks

The strategic networks include commercial networks, the Defense Communications System (DCS), the Defense Data Network (DDN), the Defense Switched Network (DSN), and the Ground Wave Emergency Network (GWEN).

3.2.1 Defense Communications System (DCS)

The DCS is the world wide strategic communications system used by the US DoD for day-to-day operations, and is the heart of the wartime communications system for the National Command Authorities, the Joint Chiefs of Staff, the Commanders-in-Chief, and other critical users. It comprises government-owned and operated communications facilities and circuits leased from commercial telecommunications companies. The government-owned portion includes all long-haul assets of the military except those devoted to tactical communications, and are mostly based outside the U.S. Transmission media include line-of-sight radio, over-the-horizon tropospheric scatter radio, HF radio, satellites, and cable.

3.2.2 Defense Data Network (DDN)

The DDN is the successor to the Autodin II network program which was canceled in 1982. The DDN is a packet switching system based upon ARPANET. It currently connects around 750 host computers and 30,000 users.

3.2.3 Defense Switched Network (DSN)

The DSN is an overlay network designed to be part of the US telephonic common carrier system, and is replacing the dedicated AUTOVON telephone network. The DSN consists of virtual software packages which common carriers are paid to add to their digital switching nodes in existing commercial networks. The software will handle all military switching needs over regular networks, and will permit the use of encrypted voice.

AUTOVON is a world-wide, mainly analog, circuit switched network for telephone and data transmission and serves the DoD and other authorized users.

3.2.4 Ground Wave Emergency Network (GWEN)

GWEN is designed to be a survivable communications network to be used by the command and control of US strategic forces both during and after nuclear war. The network consists of a

large number of low frequency (150-175 kHz) unmanned broadcast-type radio relay stations distributed throughout the continental U.S. GWEN handles low speed (100 words per minute) data traffic and employs packet-switching for rapid re-routing of messages around destroyed or non-functioning relay stations. Thus, the system can continue to operate despite considerable damage.

3.3 Tactical Facsimile

Providing tactical facsimile services demands the best fax has to offer under extremely harsh conditions. For example, tactical facsimile equipments are often called upon to provide accurate gray scale images in conditions ranging from the heat of the desert, to the wetness of tropical forests, to the numbing cold of polar ice caps. In addition, their transmissions must be brief and secure. Tactical facsimile equipments need gray scale capabilities to provide accurate and detailed facsimiles of maps, charts, photos, etc., and brief and secure transmissions are needed to thwart enemy eavesdropping. Finally, the facsimile services must be provided over the same communication links used for secure and non-secure voice communications (telephony, radio, etc); i.e., no special communication links

Because of these requirements, the U.S. military services and the military services of other member nations of the North Atlantic Treaty Organization (NATO) devised a standard, STANAG 5000, which allows their tactical facsimiles to interoperate.[1] To wit, the STANAG 5000 standard defines secure interoperability requirements for black and white and gray scale facsimile equipments.

The STANAG 5000 standard defines two types of facsimile equipments known as Type I and Type II. Type I encompasses black and white facsimile equipments only. Type II encompasses Type I and gray scale equipments. Furthermore, the standard defines permitted modes of interoperability. For example, one equipment transmitting simultaneously to several equipments, operation over simplex, half duplex, and full duplex links.

3.3.1 STANAG Type I - Black and White Imagery

The STANAG Type I standard defines the requirements for a baseline system providing black and white facsimile transmissions. It is the military equivalent of a commercially available Group 3 equipment.

3.3.1.1 Communication Protocol

Facsimile equipments (Type I or Type II) adhering to the STANAG standard use a digital interface for data exchange. The developers of the STANAG standard felt that digital communications are easier to safeguard than analog communications, and using a digital interface allows users to take advantage of existing digital encryption devices. In general, a STANAG compliant equipment connects to an encryption device which in turn connects to a communications equipment. Given this configuration, STANAG compliant equipments are usually unaware of the encryption of their transmissions and how their transmissions get to their destinations. Nevertheless, they are aware of the protocol which allows them to synchronize with other STANAG compliant equipments for the purpose of controlling and exchanging documents. The protocol is relatively simple (as compared to Group 3 or Group 4). In general, it uses two flags, Start of Message (SOM) and End of Message (EOM) to indicate the start and end, respectively, of a page of a facsimile document.

3.3.1.2 Data Compression

Type I facsimiles may be sent using one of three compression formats:

1. Uncompressed facsimile data with line synchronization codes.
2. Compressed facsimile data using one-dimensional run-length codes.
3. Compressed facsimile data using one-dimensional run-length codes (like 2.) and Forward Error Correction (FEC).

These three formats provide different degrees of transmission durations, reduced equipment complexity, and data integrity. Unfortunately, improving one often comes at the expense of at least one of the other two. For example, improving error correction often results in lower compression ratios and higher equipment complexity (See Table 3-1).

The data compression technique for (2) and (3) uses the one dimensional portion of the International Telegraph and Telephone Consultative Committee's (CCITT) Group 3 coding scheme (CCITT Recommendation T.4). Nevertheless, this doesn't mean documents can be exchanged between a STANAG compliant equipment and a Group 3 compliant equipment. Both the modems and the protocols are different.

Table 3-1. Comparison of Transmission Methods

Method	Compression	Error Correction	Complexity
Uncompressed	None	Minimal	Small
Compressed	Highest	Moderate	Moderate
Compressed with Error Correction	Moderate	Best	High

The one-dimensional portion of the CCITT's coding scheme (as well as the two-dimensional portion) codes documents according to a fixed, non-adaptive coding table. In general, it assumes short black runs will be separated by long white runs. The CCITT developed this table based upon studies which indicated most facsimile transmissions are usually textual, and which demonstrated "acceptable" compression ratios could be achieved for most documents using a code table determined from a few sample documents. Moreover, the fixed code table scheme, as opposed to most adaptive coding schemes, is relatively easy to implement.

3.3.1.3 Transmission Rate

STANAG compliant equipments typically operate at a rate determined by the connected communications equipment (their clock rate is derived from the communications equipment). Nevertheless, they must be able to interoperate at 2.4 and 16 Kilobits per second (Kbps), and at rates between 1.2 and 16 Kbps. Thus, for an uncompressed 8½ x 11 inch document (1728 pels x 1076 lines) transmission times of roughly 2 minutes at 16 Kbps can be expected, or 25 minutes at 1.2 Kbps. If compression is used and a minimum compression of 10:1 is achieved, then compressions times of 12 seconds for 16 Kbps and 2.5 minutes for 1.2 Kbps can be realized. One could conclude from this that compression "increases" transmission rates and is therefore desirable. This would be especially true for lower rate communications where long transmissions risk revealing friendly positions to the enemy, or unnecessarily "tie up" a communications network or link which might be needed for other, possibly higher priority, verbal or non-verbal communiques.

3.3.2 STANAG Type II - Gray Scale Imagery

STANAG Type II compliant equipments improve on the Type I equipments by allowing the transmission of three types of gray scale images. These image types differ only in the permitted shades of gray; for example, an image type may have either 4, 8, or 16 shades of gray.

3.3.2.1 Communication Protocol

The protocol used for Type II transmissions is identical to that used for Type I transmissions with a few exceptions; special codes are used to indicate gray scale, low resolution, and auto resolution data follow.

3.3.2.2 Data Compression

Gray scale images are preprocessed before they are encoded. First, each picture element (pixel) is reduced to one of 16 shades of gray (4 bits), and, if necessary, is further reduced (for instance, to 3 bits). Once reduced, the bits of the pixels are processed as bit planes. For example, all the most significant bits are encoded, then the next most significant bits, and so on. Thus, each plane is treated as a separate black and white image.

Like Type I, Type II compliant equipments may send documents using one of three compression formats:

1. Uncompressed facsimile data with line synchronization codes.
2. Compressed facsimile data; where one-dimensional run-length codes are used to encode horizontal and vertical pel correlations.
3. Compressed facsimile data with Forward Error Correction; where one-dimensional run-length codes are used to encode horizontal and vertical pel correlations (like 2.).

Gray scale images are compressed by taking advantage of both horizontal and vertical pel correlations; adjacent lines are wobbled (See Figure 3-1). In addition, in areas where the gray scale pictorial information varies slowly, further compression is achieved by using an auto

resolution algorithm to select a good transmission resolution.

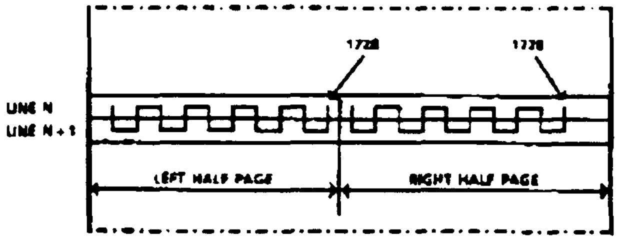


Figure 3-1. Example of a "Wobbled" Line

Auto resolution takes advantage of the low resolution regions of gray scale images to increase the achievable compression. In general, lower order bit planes have little effect on the perceived resolution, and, as a consequence, may be transmitted at lower resolutions in regions of slow intensity variation. Which bit planes are affected is determined during the compression process. To perform a half resolution, a majority logic decision is performed on for bits of the bit plane being encoded. The result is a single bit which represents the average of the four original bits.

3.3.2.3 Transmission Rates

Type II transmissions occur at the same rates as Type I transmissions. Nevertheless, the duration of a document (gray scale, 8½ x 11) transmission can take up to four times as long as Type I transmissions, depending on the mode of transmission (uncompressed, compressed, etc.), and whether auto resolution is used.

3.4 Strategic Facsimile

The name "strategic" tends to imply that all strategic facsimile equipments have capabilities tactical facsimile doesn't. The reverse is true. Most strategic facsimile equipments are the same Group 3 equipments found in offices and homes. Unlike tactical facsimile, Group 3 equipments cannot send encrypted data, and they are unable to send true gray scale images. These equipments are known as "strategic" facsimile because of who uses them (Government agencies, military commands, etc.), and how they use them (Intra-agency, interagency, and industry communiques). Generally speaking, any facsimile equipment which has not been ruggedized for the battlefield can be called a strategic equipment. For example, where secure transmissions are needed, Group 3 equipments modified to be able to connect to encryption devices like Secure Telephone Units (STU; STU-III is a commonly used encryption device) can be used, or, for transmissions to tactical equipments, hybrid equipments (Group 3 and STANAG 5000 compliant) can be used.[2] Where each is used depends entirely on the user's needs, and to some extent cost.

For example, the commercially available equipments are usually the cheapest and are used by those in the government who need neither encryption nor the ability to communicate with tactical facsimile equipments, but do need to be able to send facsimiles to public and private businesses. Modified commercially available equipments are the next least expensive and are used by the government (and government contractors) needing encryption. Hybrid equipments are the most expensive and are used by the government (usually the military) needing to communicate with tactical equipments.

3.4.1 Group III Facsimile

Today, the majority of strategic facsimile equipments used by the U.S. Government, and in the private sector, are Group 3 compliant equipments. Moreover, the current widespread use and acceptance of fax is a direct result of the robustness of the Group 3 CCITT Recommendations. Group 3 couples short transmission durations with automatic equipment operation using the PSTN. For instance, prior to Group 3 a page could take up to 6 minutes to be transmitted to its destination, required almost constant supervision, and equipments were expensive. With Group 3, per page transmissions were reduced to less than 30 seconds, and documents could be sent or received automatically with no operator intervention inexpensively. These three factors, fast transmissions, ease of operation, and low cost, are probably the most important reasons Group 3 fax is so popular today.

Nevertheless, Group 3 equipments can not be used "as is" by the U.S. Government on secure digital networks; they are designed to operate over the analog PSTN. With modification, however, they can operate on secure digital networks. This is possible because Group 3 is neither purely digital nor purely analog. Group 3 uses both: on the PSTN an analog modem provides the carrier for the digital messages. To use a Group 3 equipment on a digital link at least two approaches can be taken: first, the modem can be bypassed, or second, a second modem can be used to convert the analog signals to digital. To date, manufacturers usually bypass the modem.

3.4.1.1 Communication Protocol

The Group 3 communications protocol is very robust, and uses a high level data link control (HDLC) format. The basic HDLC structure consists of a number of frames each of which

is subdivided into a number of fields. It provides for frame labelling, error checking, and confirmation of correctly received information. The protocol allows for manual, automatic, and a mixture of both modes of operation. Documents can be automatically sent or received without operator assistance. Documents can be sent using a resolution appropriate for the detail required as well as the desired transmission duration. Finally, equipments can have non-standard capabilities which are manufacturer dependent.

3.4.1.2 Encoding Algorithm

Group 3 uses an encoding algorithm which allows the receiver to detect and recover from errors occurring in the transmitted document. It does this by employing both one dimensional and two dimensional coding schemes. The one dimensional coding scheme uses fixed codes to represent run lengths, and by doing so allows the receiver to recover from any transmission errors. The two dimensional coding scheme provides greater compression than that which is achievable with just the one dimensional approach, but it doesn't provide any explicit error detection. Together, both are synergistic. The one dimensional coding provides the error detection and error recovery, while the two dimensional coding provides greater compression.

3.4.1.3 Transmission Rate

Group 3 is designed to operate over the PSTN at rates of 2400, 4800, 7200, 9600, 12000, and 14400 bits per second.

3.4.1.4 Planned Future Expansion

Because of Group 3's popularity, there are several improvements being considered by the CCITT:

1. Higher speed modems
2. Higher resolutions
3. Protocols for digital interfaces (in particular, ISDN)
4. Higher performance
5. An Applications Program Interface (API)

6. Facsimile routing
7. Improved bi-level compression
8. Color and Gray scale compression
9. A Binary File Transfer (BFT)
10. Standard protocol for encrypted facsimiles
11. Audiographic Conferencing
12. Store and Forward and Message Handling Systems (MHS)

Of these, several have already been approved for incorporation into the Group 3 Recommendation series. They are the higher speed modem (14.4 Kbps (V.17)), and improved bi-level compression using Group 4's T.6 Recommendation. The others are still being studied; although some are nearing approval.

Naturally, the higher speed modem will permit documents scanned at current resolutions to be transmitted more quickly. For example, the time for the data of an 8½x11 inch page scanned at 196x204 pels/inch and transmitted at 9.6 Kbps with a compression of 10:1 to arrive at its destination is approximately 39 seconds; whereas, the same page sent at 14.4 Kbps takes approximately 26 seconds. Transmitting documents using the higher resolutions will still take longer. For example, the same page scanned at 400x400 pels per inch will require a transmission time of approximately 52 seconds, or almost one minute. Nevertheless, upgrading Group 3 now to use higher resolutions should help prepare Group 3 for its use on ISDN; where ISDN's higher transmission rates (64 Kbps) will permit high resolutions coupled with short transmission times (approximately 12 seconds for an 8½x11 inch page scanned at 400x400 pels/inch).

With the advent of the higher resolutions, the CCITT is advocating a change in pel densities. Group 3 uses a pel density of either 98x204 or 196x204 pels per inch (rectangular). In addition to the rectangular higher pel densities of 196x408 and 392x408, the higher pel densities of 300x300 and 400x400 pels per inch (square) are being proposed. Although the resolutions are different the densities are also different (rectangular versus square). Newer equipments can use the new square pel densities and still be able to transmit to or receive from older equipments which use rectangular pels. Nevertheless, some distortion will occur; but it is minor, is averaged over the whole document, and, in general, amounts to about two percent (Compare Figure 3-2 to Figure 3-3). This means that unless the original is available for comparison, a casual observer will probably be unable to discern the difference.

Table 3-2. Group 3 Resolutions

Code bits in DIS/DTC (X denotes don't care)						Resolution Capabilities					
bit 46	bit 45	bit 43	bit 42	bit 41	bit 15	8 x 7.7 line/mm	8 x 15.4 line/mm	16 x15.4 line/mm	200 x 200 pels/25.4 mm	300 x 300 pels/25.4 mm	400 x 400 pels/25.4 mm
X	X	X	0	0	1	X					
X	X	X	0	1	0		X				
X	X	X	0	1	1	X	X				
X	X	X	1	0	0			X			
X	X	X	1	0	1	X		X			
X	X	X	1	1	0		X	X			
X	X	X	1	1	1	X	X	X			
0	0	1	X	X	X				X		
0	1	0	X	X	X					X	
0	1	1	X	X	X				X	X	
1	0	0	X	X	X						X
1	0	1	X	X	X				X		X
1	1	0	X	X	X					X	X
1	1	1	X	X	X				X	X	X

One of the improvements that has strong U.S. support is a Group 3 protocol for ISDN. It builds on the existing Group 3 protocol and its modifications will allow Group 3 equipments to take advantage of ISDN's 64 Kbps. The major difference between the two is that the ISDN protocol does not use an analog modem. Transmissions are purely digital and, since the modem is not used, can exceed the limits imposed by the transmission capability of the modem (now a maximum of 14.4 Kbps). Nevertheless, analog equipments will not be forgotten. During an exchange on the ISDN between a "digital" Group 3 equipment and an "analog" equipment, the "digital" equipment must fall back to the "analog" equipment's mode of communication. Therefore, an "ISDN" Group 3 equipment must also support analog transmissions. Moreover, because the modem is being bypassed, thought is now being given as to what digital physical interface should be used for ISDN. One candidate is the RS-232 interface. Its advantages are that it is a commonly used digital interface, and it has been used before by manufacturers desiring

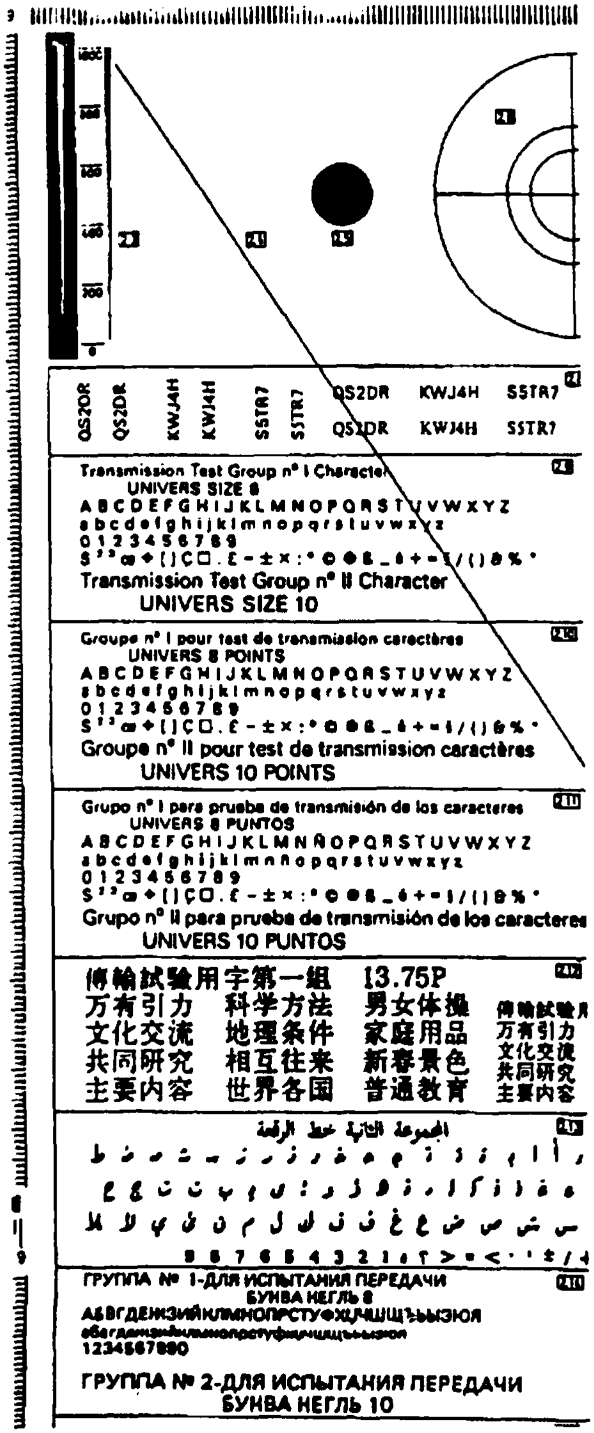


Figure 3-2. Original Scanned with Square Pels

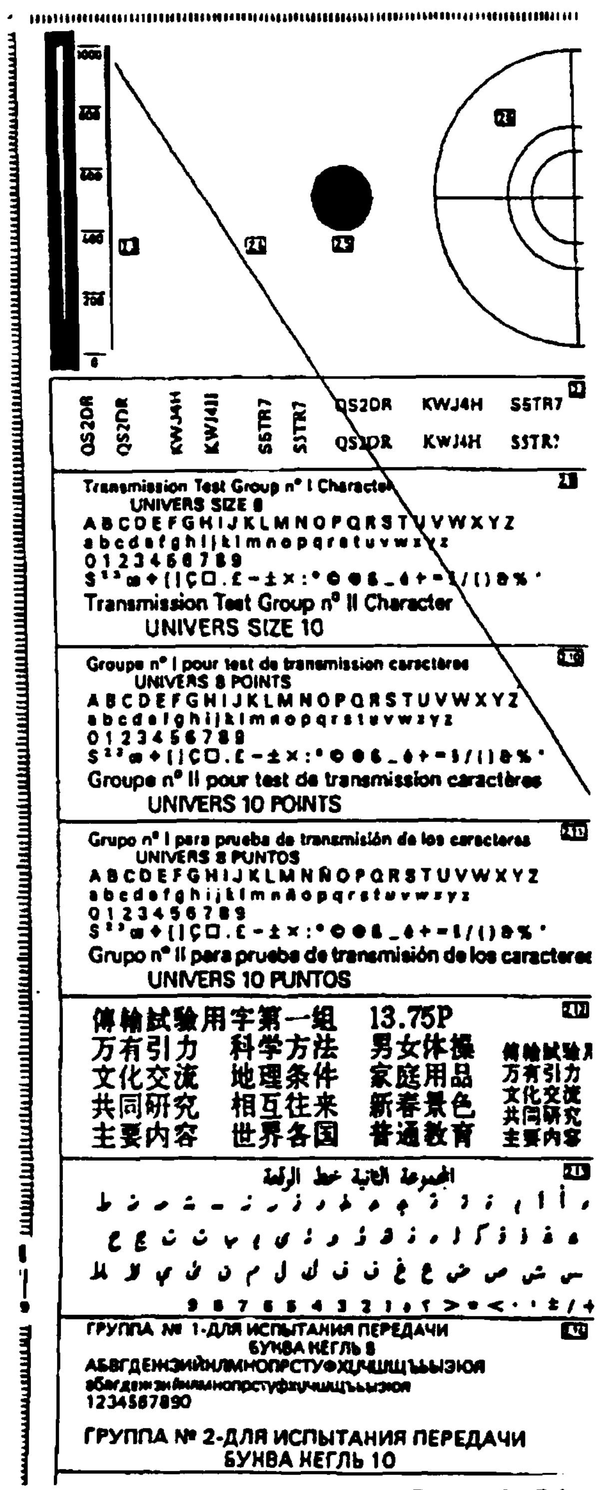


Figure 3-3. Facsimile Printed using Rectangular Pels

a digital interface on facsimile equipment. Finally, the proposed ISDN Group 3 protocol requires the use of the optional HDLC error correction mode, and requires the use of the advanced compression techniques as described by Recommendation T.6 (Group 4 compression techniques).

Higher performance covers a host of issues: streamlining Group 3's protocol, using higher speeds for capability exchanges (greater than 20 Kbps), and so forth.

Applications Program Interface is intended to provide a common hardware interface and control structure (protocol and instructions) for application developers who develop software products for PC facsimile cards, etc. This common interface would allow developers to construct software packages without worrying about with whose hardware it would be connected.

Today, facsimile equipments can not direct a call to a specific phone extension, Facsimile routing would correct this. In the short term, it could be implemented using Multifrequency Pushbutton (MFPB) signalling, Optical Character Recognition (OCR), or character transmission. In the long term, modifications to the Group 3 protocol (Recommendation T.30) might be necessary.

In addition to using T.6 for compression, greater compression could be achieved by using the Joint Bi-Level Experts Group's (JBIG) bi-level compression algorithm, or the Joint Photographic Experts Group's (JPEG) compression algorithms could be used for gray scale and color transmissions. JPEG was formed at the end of 1986 under the umbrella of the ISO working group (now ISO/IEC/JTC1/SC2/WG8 - Coded Representation of Picture and Audio Information). It brings together ISO picture coding knowledge and CCITT telecommunications service expertise (from the New Image Communications (NIC) group of CCITT Study Group VIII). Its aim is to select and develop compression/decompression techniques for natural color and gray scale images. JBIG is a related working group devoted to bi-level (binary or black and white, no gray scale) images.

With regard to binary file transfers (BFTs), the Group 3 protocol could be modified to allow binary file transfers from one computer system to another using fax modems, a capability it now lacks. BFT is highly desirable for equipments (Personal computers, workstations, etc., with fax boards) and other systems which handle both facsimile transmissions and binary file transfers. Currently, PCs use *full* duplex modems for file or bulk data transfers over the PSTN.

These full duplex modems are normally used for interactive sessions with other computer systems where messages must flow in both directions simultaneously, and are not geared towards bulk data transfers. In contrast, the *half* duplex of the fax modem is geared towards bulk data transfers: it permits data to flow in only one direction at a time, but at much higher speeds than those achievable with full duplex.

Group 3 equipments modified to operate with encryption devices are now used by the Federal Government. These equipments use a digital port, and a separate protocol to interface with an encryption device. Currently, an ad hoc subcommittee formed under the auspices of the Telecommunications Industry Association (TIA) TR-29 committee is studying the interface and the protocol modifications needed to standardize this service. The subcommittee is considering a protocol based on one developed by Ricoh, and which is currently used by the majority of manufacturers. Ricoh's protocol is tailored towards the STU-III Secure Telephone.

Finally, Group 3 could eventually be modified to make it easier to use in audiographic conferencing and MHS applications. For example, the protocol could be modified to allow Group 3 to operate in multipoint networks (Group 3 is now a point to point service), or to operate with MHS. Because of the robustness of these two services, their requirements may encompass issues now being discussed for Group 3. For example, facsimile routing is a MHS consideration. Therefore, in some cases, it may be appropriate to resolve "large scale" services such as audioconferencing and MHS before resolving "small scale" issues such as facsimile routing.

3.4.2 Group IV Facsimile

Group 4 is the latest set of CCITT facsimile Recommendations, and was primarily designed for operation on digital, error-free, high-speed networks such as public data networks, packet-switched networks, and the ISDN. Moreover, there are three types of Group 4 equipments with characteristics as shown in Table 3-3:

Class 1: A terminal able to *send* and *receive* facsimile documents.

Class 2: A terminal, in addition to having Class 1 capabilities, able to *receive* teletext and mixed-mode[1] documents.

Class 3: A terminal, in addition to having Class 1 and Class 2 capabilities, able to *generate* and *send* teletext and mixed-mode documents.

Table 3-3. Group 4 Class Characteristics

	Class		
	1	2	3
Pel-density of scanner-printer (pels/25.4mm)	200	300	300
Pel transmission density (pels/25.4mm)	200	200/300	200/300
Pel transmission conversion capability	not required	required	required
Mixed-mode capability	not required	not required	required
Optional pel density of scanner-printer	300/400	400	400
Combined with pel transmission density (pel/25.4mm)	200/300/400	200/300/400	200/300/400
Storage	not required	not required	required

1 Mixed-mode documents contain a mixture of teletext and facsimile data on the same page. For example, a page consisting of line art and text could be sent as a mixed-mode document; the line art could be sent as facsimile data, and the text could be sent as teletext data.

These three classes provide a wide range of capability. For example, Group 4 Class 1 is similar to Group 3 (low capability), while Classes 2 and 3 permit interoperation with Teletex and mixed-mode equipments (higher capability). Nevertheless, being Group 4 compliant does not mean different classes of Group 4 equipments can interoperate. For instance, a careful examination of Group 4's communication protocols (See Figure 3-4) reveals slight differences which prevent communications between Class 1 and Class 3 equipments (T.521 versus T.522, etc.).

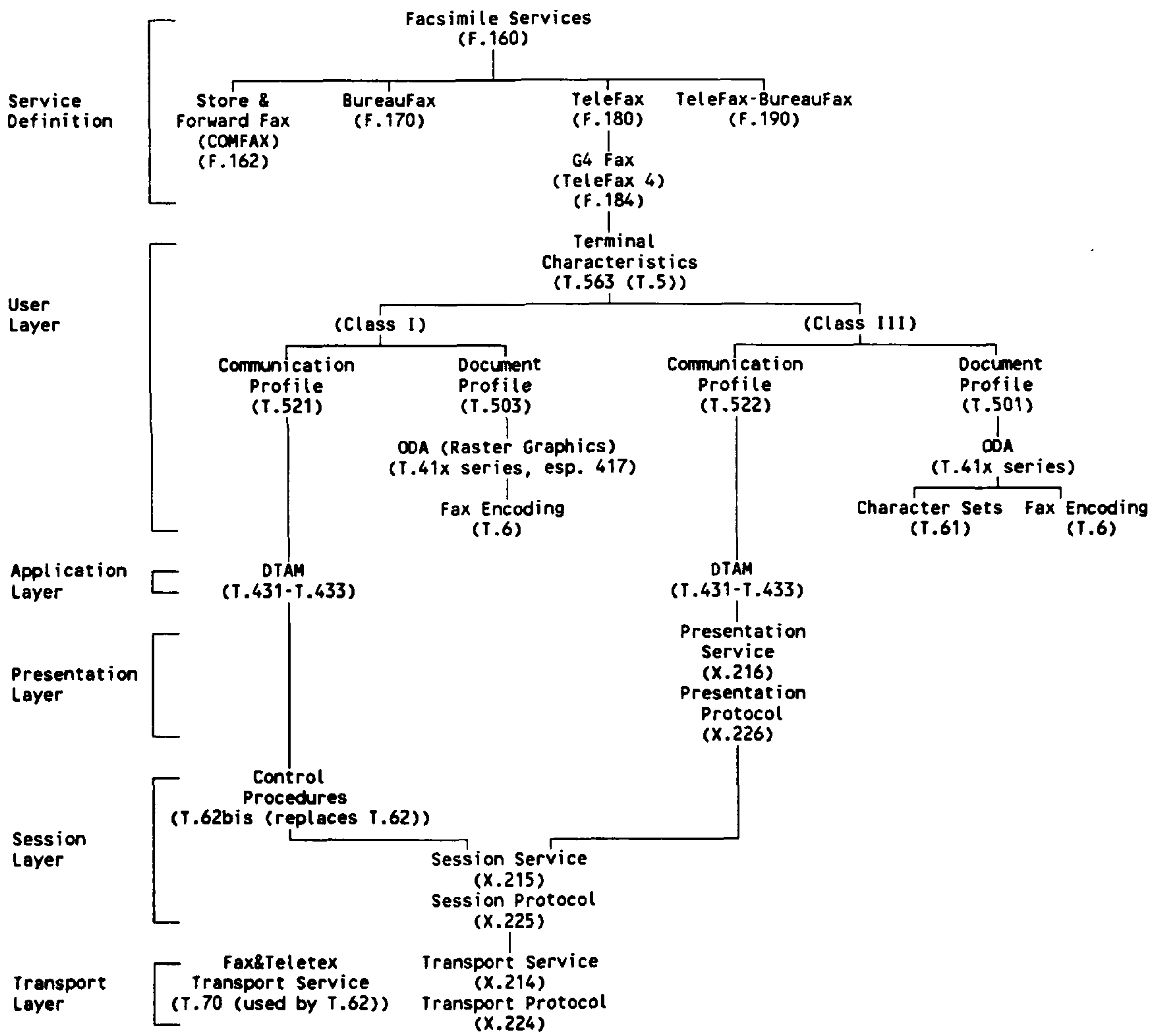


Figure 3-4. Hierarchy of CCITT Recommendations for Group 4 Facsimile

3.4.2.1 Communication Protocol

The development of the protocol structure for Group 4 has followed a rather rocky road and as a result its protocol and classes were fractured into two camps. One (Group 4 Class 1) uses a protocol designed specifically for Group 4 facsimile, while the other (Group 4 Classes 2 and 3) uses a protocol designed to connect to many different types of systems and equipments (computer systems, facsimile equipments, etc.). This fracture occurred for two main reasons: 1) the CCITT's Document Architecture Recommendations (DTAM), upon which Group 4 depends, were published prematurely (Recommendation T.73), and 2) through an oversight, the protocol for Group 4 Class 1 equipments was not made identical to the protocol for Group 4 Classes 2 and 3 when DTAM was later revised. The premature publishing of the DTAM Recommendations allowed several manufacturers to build Group 4 equipments (especially Class 1) with the underlying assumption that the CCITT Group 4 Recommendations, of which DTAM is a part, were stable. Unfortunately, this was not true. At this same time, the CCITT was considering incorporating into Group 4 the concepts embodied by the International Organization for Standardization's (ISO) Open Systems Interconnection (OSI) standard.[3],[4] OSI is designed to permit many different types of systems to communicate with one another (especially computer systems), and is not tailored towards any particular equipment or system. The CCITT decided to make Group 4 OSI compliant, and, as a result revised DTAM to be OSI compliant (now Recómmendations T.431-433). This created a dilemma. The equipments made according to the original Recommendations (T.73, etc.) would no longer be Group 4 compliant. So, the manufacturers who had already made these equipments requested that Group 4 Class 1 equipments keep their original protocol, and they were accomondated. As a result, the CCITT also, inadvertently, excluded Group 4 Class 1 equipments from using the newer, OSI compliant protocol (Both protocols should probably have been allowed). Since then several attempts have been made to bring Group 4 Class 1 equipments in line with the revised DTAM Recommendations, and the OSI standards (See Figure 3-4, change from T.62 to T.62bis, and change from T.70 to X.215, etc.). Nevertheless, Group 4 Class 1 equipments are still unable to communicate with Group 4 Class 2 or Class 3 equipments, or vice versa.

OSI consists of a seven-layer model or framework which ensures that all new communication standards are compatible. Secondly, a system obeying the OSI model in its communication with other systems is termed an "open system". The OSI open systems concept

allows application processes such as Group 4 fax to interact with any other application process anywhere in the world.

The seven layers of the OSI model are divided among three different functions: user interaction, interface, and communication network interaction (See Figure 3-5).

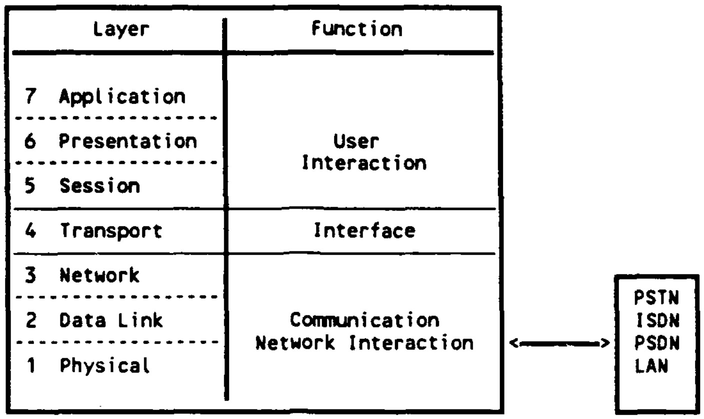


Figure 3-5. The OSI Model

Table 3-4. CCITT Recommendations Pertaining to ISDN Group 4 Operations

User Layer

T.563	Terminal Characteristics for Group 4 Facsimile Apparatus
T.521	Communications Application Profile BT0 for Document Bulk Transfer Using the Session Service Defined in Recommendation T.62bis (Group 4 Class 1)
T.522	Communications Application Profile BT1 for Document Bulk Transfer (Group 4 Classes 2 and 3)
T.501	A Document Application Profile MM for the Interchange of Formatted Mixed Mode Documents
T.503	A Document Application Profile for the Interchange of Group 4 Facsimile Documents
T.41x	Recommendations relating to the definition of an Open Document Architecture
T.6	Facsimile Coding Schemes and Coding Control Functions for Group 4 Facsimile Apparatus
T.61	Character Repertoire and Coded Character Sets for the International Teletex Service

Application Layer

T.431-3	Document Transfer and Manipulation (DTAM) introduction, service definition, and protocol specification.

Presentation Layer

X.216	Presentation Service Definition for Open Systems Interconnection for CCITT Applications
X.226	Presentation Protocol Specification for Open Systems Interconnection for CCITT Applications

Session Layer

X.215	Session Service Definition for Open Systems Interconnection for CCITT Applications
X.225	Session Protocol Specification for Open System Interconnection for CCITT Applications
T.62bis	Control Procedures for Telex and Group 4 Facsimile Services Based on Recommendations X.215/X225

Transport Layer

X.214	Transport Service Definition for Open Systems Interconnection (OSI) for CCITT Applications
X.224	Transport Protocol Specification for Open Systems Interconnection for CCITT Applications
T.70	Network-Independent Basic Transport Service for the Telematic Services

Network Layer

X.25	Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode and Connected to Public Data Networks by Dedicated Circuit
X.21	Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Synchronous Operation on Public Data Networks

Data Link Layer

X.75	Terminal and Transit Call Control Procedures and Data Transfer System on International Circuits Between Packet-Switched Data Networks
T.71	LAPB Extended for Half-Duplex Physical Level Facility

Physical Layer

X.21bis	Use on Public Data Networks of Data Terminal Equipment (DTE) which Is Designed for Interfacing to Synchronous V-Series Modems
V.24	List of Definitions for Interchange Circuits Between Data Terminal Equipment and Data Circuit-Terminating Equipment

The seven layers have the following definitions, and Table 3-4 describes the Group 4 Recommendations belonging to each layer:

Application	- The highest level. It is the user interface between Group 4 fax or other services and the OSI environment.
Presentation	- The presentation layer handles session establishment and termination requests, and it preserves the meaning of data while resolving syntax differences.
Session	- The session layer establishes, manages, and releases the communication connection.
Transport	- Acts as a consistent interface between the application-related functions and the transmission-related functions.
Network	- Provides routing and relaying through switched telecommunication media.
Data Link	- Reliably transfers all information over the physical transmission media.
Physical	- Deals with the transmission of a bit stream, regardless of its meaning, across a physical communication medium.

In addition, Group 4, regardless of the protocol stack used, adheres to the CCITT's Open Document Architecture (ODA) concept. The ODA facilitates the interchange of documents to permit the following items:

- different types of content, including text, image, graphic, and sound, can coexist within a document.
- the intentions of a document originator with respect to editing, formatting, and presentation is communicated effectively.

To this end, ODA defines three forms of document representation:

Formatted Form	-	Documents are presented as intended by the originator.
Processable Form	-	Documents may be edited and formatted.
Formatted Processable Form	-	Documents may be presented, edited, and reformatted.

Of these three, Group 4 uses the formatted form.

3.4.2.2 Encoding Algorithm

The basic coding scheme is the same, in principle, as Group 3's two-dimensional coding scheme. Major differences between the two are 1) Group 4 does not use one-dimensionally coded lines, and 2) Group 4 does not use "end of line codes" except as end of facsimile information indicators (i.e., they are not present on a line by line basis). To jump start a document's facsimile encoding, Group 4 places an imaginary white line at the beginning of the facsimile data.

3.4.2.3 Transmission Rate

Intended Group 4 transmission rates are 56K bps and 64K bps (ISDN). If an 8½ x 11, 400 pel per inch document is sent compressed (say 10:1) at 64K bps, it will take 23.3 seconds for it to arrive at its destination. If it were a 200 pel per inch document, it would take 5.8 seconds.

3.4.2.4 Planned Future Expansion

The CCITT would like Class 3 terminals to be able to present documents, and permit editing and reformatting (Formatted Processable form). In addition, the CCITT would like equipments adhering to the different classes to be able to interoperate. They are considering a new Group 4 Class 1 which would be able to interoperate with Classes 2 and 3, and which would coexist with today's Group 4 Class 1. Finally, like Group 3, efforts are underway to simplify or permit Group 4's operation in audiographic conferencing and MHS applications, as well as permitting the transmission of gray scale and color documents.

4.0 COMPATIBILITY ANALYSIS

Table 4-1. Comparison of Strategic and Tactical Facsimile

Tactical	Strategic
- multipoint - black and white - gray scale - receipt acknowledgments are not required - simple protocols - no nonstandard capabilities - autoresolution for gray scale	- point-to-point - black and white only - receipt acknowledgements required - complex protocols - nonstandard capabilities

At present, strategic and tactical facsimile equipments are incompatible with one another, and the differences in their protocols appear to be too great for simple reconciliations (See Table 4-1 and Table 4-2). Compounding this are the protocol differences evident within the strategic facsimile services; Group 3 is unable to interoperate with Group 4, Group 4 is unable to interoperate with Group 3, Group 4 Class 1 is unable to interoperate with Group 4 Classes 2 and 3, and vice versa. In general, the tactical facsimile service is more robust than the strategic facsimile service. The tactical facsimile service (STANAG 5000) provides black and white or gray scale facsimiles simultaneously to multiple receivers (multipoint) over almost any type of network (telephony, digital, radio, etc.) without requiring receipt acknowledgements. Compare this to the strategic facsimile service which provides only black and white facsimiles to just a single receiver (point to point) over PSTN-like or digital networks and requires receipt acknowledgements.

Forming a unified facsimile service using these protocols, strategic and tactical, may be impractical. Nevertheless, there is some merit in placing one or more of them into one equipment; for example, the military needs a few equipments which are able to interoperate with both Group 3 and STANAG 5000 equipments. These hybrid equipments could contain both protocols; where the protocols retain their separate identities and the equipments must determine when to use which protocol. In fact, this approach has already been taken by the U.S. Government. The Department of Defense (DoD) has published a facsimile standard, MIL-STD-188-161B, which stipulates the types of protocols government facsimile equipments may use.

In MIL-STD-188-161B, interoperability between tactical and strategic facsimile is accomplished by requiring the use of "STANAG 5000" for all secure (classified) transmissions, and the optional use of Group 3 for unclassified transmissions. This standard is noteworthy because it legitimizes the use of more than one protocol in one machine. Manufacturers can, if

they like, construct equipments capable of communicating with both Group 3 and STANAG 5000 equipments, and do so in an accepted format. This standard does not, however, attempt to combine the protocols themselves.

In addition, MIL-STD-188-161B fails to consider classified transmissions solely among strategic equipments. For example, it does not consider STU-III encrypted, digitalized Group 3 transmissions (Group 3 Ricoh), nor does it consider encrypted or unencrypted Group 4 transmissions. *Encrypted* Group 3 transmissions are of particular importance because Group 3 Ricoh allows Government agencies to use secure fax in the office environment without paying for expensive, ruggedized, sometimes bulky equipments which were designed for the battlefield, and which may have more capability than needed (multipoint, gray scale, etc.). Secondly, by adding a fax modem for the PSTN, the Group 3 Ricoh equipments can be easily and cheaply made to communicate with the large and dominant base of Group 3 equipments.

Although a unified facsimile service incorporating all existing protocols may be impractical, it might be realistic to expect one of them to eventually dominate the others, to absorb most of their capabilities, and to force the others into obsolescence. Today, the Group 3 service appears to be heading in this direction propelled by the widespread popularity of its equipments. The CCITT and TIA are supporting this movement, either intentionally or unintentionally, by doing such things as proposing standards for interfacing with encryption devices, proposing standards for interfacing with digital networks like the ISDN, providing finer resolutions, providing higher speed modems, and considering gray scale and color. For example, providing enhanced capabilities, like finer resolutions and allowing Group 3 equipments to operate on the ISDN, is likely to bring Group 3 into direct conflict with Group 4. Group 4 already operates on digital networks and provides high resolution facsimiles; but, with Group 3's migration to ISDN coupled with comparable resolutions, comparable compression techniques, and interoperability with its large base of existing analog equipments (PSTN), which Group 4 doesn't have, Group 4 may be no match. What might offset this is the structured approach of Group 4, Group 4's OSI and mixed-mode capabilities, and its better suitability for packet switched networks, and MHS systems, where Group 3's nonstandard facilities capability is difficult to implement. Nevertheless, were Group 3 to also include all or most of these capabilities, Group 4 would indeed be in trouble.

It is unlikely that STANAG 5000 would eventually dominate all other facsimile protocols. It is a specialized protocol designed by a small number of nations (NATO) for a specific task

(battlefield facsimile transmissions). Nevertheless, it does have capabilities the internationally accepted facsimile standards do not (gray scale, multipoint operation, transmission encryption, etc.). These capabilities could be useful to a single dominant protocol, and almost mandatory if it is to supplant STANAG 5000. There is some movement in this direction. As mentioned before, gray scale and color facsimile transmissions are being considered by the CCITT for Group 3 and Group 4, and standards for connecting Group 3 to encryption devices are also being considered. What is not being considered, at the moment, is multipoint operation for either Group 3 or Group 4, and a viable heir to STANAG 5000 should have multipoint capability.

Another item to consider is that the historically autonomous nature of facsimile equipment is being encroached upon by computers and other systems. This is evident in the proliferation of fax cards for PCs, and in the addition of digital ports to facsimile equipments for the purpose of connecting them to computers, encryption devices, etc. (See Figure 4-1 through Figure 4-4). By connecting facsimile equipments to computer systems, the facsimile equipments are being used as multifunction peripherals. To a computer, a facsimile equipment can be a scanner, a printer, a facsimile and binary file transfer port, a compression or decompression engine, an

Table 4-2. Interoperability of Facsimile Equipments

Transmitter \ Receiver	Group 3 (analog)	Group 3 ISDN	Group 3 Ricoh	STANAG 5000	MIL-STD-188-161B	G3 Ricoh & STANAG 5000	Group 4 Class 1	Group 4 Classes 2 & 3
Group 3 (analog)	•	•			•			
Group 3 ISDN	•	•			•			
Group 3 Ricoh			•			•		
STANAG 5000				•	•	•		
MIL-STD-188-161B	•	•		•	•	•		
Ricoh & STANAG 5000			•	•	•	•		
Group 4 Class 1							•	
Group 4 Classes 2 & 3								•

Legend:
• interoperable
shaded minor modifications required for interoperability
blank major modifications required for interoperability

encryption device, etc. Clearly, this undermines the formerly standalone nature of facsimile machines. To adapt, it may be necessary to redefine what a facsimile equipment is. For instance, several different types might be defined: one molded in the form of the historical machine - fax port only, one with both a computer port and a fax port, one with both a peripheral port and a fax port, and one with three ports: a computer port, a peripheral port, and a fax port.

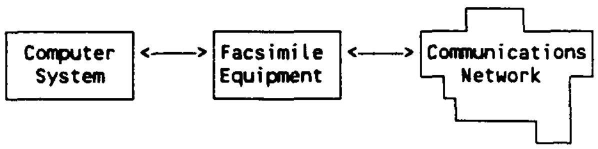


Figure 4-1. Computer Controlled Facsimile Equipment

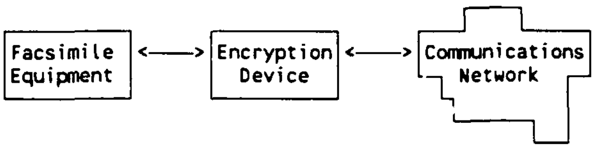


Figure 4-2. Facsimile Equipment with In-line Encryption

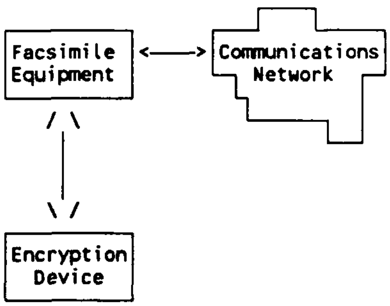


Figure 4-3. Facsimile Equipment with Peripheral

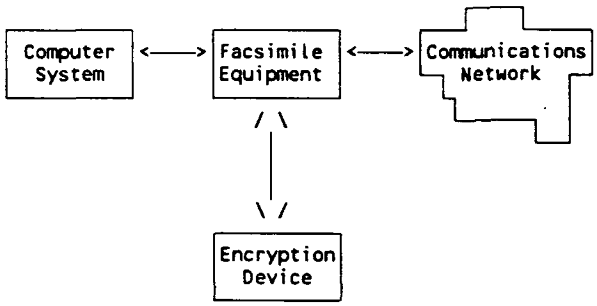


Figure 4-4. Computer Controlled Facsimile Equipment with Peripheral

5.0 RECOMMENDATIONS

Allowing tactical and strategic facsimile equipments to interoperate necessitates the intertwining of national (Group 3 Ricoh), NATO (STANAG 5000) and international (Group 3, etc.) standards. MIL-STD-188-161B is a step in this direction; it combines STANAG 5000 and Group 3 (analog). Nevertheless, advances now being made on the international scene under the auspices of the CCITT should also be considered, especially if a single facsimile standard is desired. Therefore, two strategies are proposed: one short term, the other long term. The short term strategy is to modify MIL-STD-188-161B to allow Group 3 equipments to transmit classified information over secure point-to-point communication links (Group 3 Ricoh) in place of or in conjunction with STANAG 5000. Doing so would allow government agencies to purchase cheaper Group 3 equipments modified for secure transmissions instead of specialized (and possibly expensive) combined Group 3 and STANAG 5000 equipments.

Since it appears that a unified protocol may be impractical, the long term strategy is to modify existing protocol standards (especially Group 3) to include features found in tactical facsimiles (gray scale, etc.) and enhancements like color, and to let the marketplace decide which protocol should be dominant. Some modifications which might be made are listed below:

- Transmission of gray scale images
- Transmission of color images
- Higher resolutions with consistent pel densities
- Better compression algorithms
- Communication ports and protocols designed to permit use of encryption devices
- Allowance for system and peripheral ports
- Store-and-forward applications
- Network independence (OSI compatibility)
- Multipoint operation

REFERENCES

[1] "*STANDARDIZATION AGREEMENT, Subject: Interoperability of Tactical Digital Facsimile Equipment*," STANAG 5000 (Edition 2), North Atlantic Treaty Organization (NATO), Miltary Agency for Standardization (MAS), 5 December 1986

[2] "*MILITARY STANDARD - Interoperability and Performance Standards for Digital Facsimile Equipment*," MIL-STD-188-161B, Department of Defense, United States of America, 30 March 1990

[3] "*Data Communication Networks Open Systems Interconnection (OSI) Model and Notation, Service Definition*," Blue Book, Volume VIII, Fascicle VIII.4, Recommendation X.200, pp. 3-56, CCITT, 1988

[4] Kenneth R. McConnell, Dennis Bodson, Richard Schaphorst, "*FAX, Digital Facsimile Technology & Applications*," pp. 85-99, Artech House, 1989

APPENDIX A

STANAG 5000
(Edition 2)

NORTH ATLANTIC TREATY ORGANIZATION
(NATO)

MILITARY AGENCY FOR STANDARDIZATION
(MAS)

STANDARDIZATION AGREEMENT

SUBJECT: INTEROPERABILITY OF TACTICAL DIGITAL FACSIMILE EQUIPMENT

Promulgated on 5 December 1986

M. KORKOLIS
Major-General, HEAR
Chairman, MAS

RECORD OF AMENDMENTS

No.	Reference/date of amendment	Date entered	Signature

EXPLANATORY NOTES

AGREEMENT

1. This NATO Standardization Agreement (STANAG) is promulgated by the Chairman MAS under the authority vested in him by the NATO Military Committee.

2. No departure may be made from the agreement without consultation with the tasking authority. Nations may propose changes at any time to the tasking authority where they will be processed in the same manner as the original agreement.

3. Ratifying nations have agreed that national orders, manuals and instructions implementing this STANAG will include a reference to the STANAG number for purposes of identification.

DEFINITIONS

4. Ratification is "The declaration by which a nation formally accepts the content of this Standardization Agreement".

5. Implementation is "The fulfilment by a nation of its obligations under this Standardization Agreement".

6. Reservation is "The stated qualification by a nation which describes that part of this Standardization Agreement which it cannot implement or can implement only with limitations".

RATIFICATION, IMPLEMENTATION AND RESERVATIONS

7. Page iii gives the details of ratification and implementation of this agreement. If no details are shown it signifies that the nation has not yet notified the tasking authority of its intentions. Page iv (and subsequent) gives details of reservations and proprietary rights that have been stated.

RATIFICATION AND IMPLEMENTATION DETAILS
STADE DE RATIFICATION ET DE MISE EN APPLICATION

NATION	NATIONAL RATIFICATION REFERENCE DE LA RATIFICATION NATIONALE	NATIONAL IMPLEMENTING DOCUMENT NATIONAL DE MISE EN APPLICATION	IMPLEMENTATION/MISE EN APPLICATION					
			FORECAST DATE DATE PREVUE			ACTUAL DATE DATE REELLE		
			NAVY MER	ARMY TERRE	AIR	NAVY MER	ARMY TERRE	AIR
BE								
CA	2441-5000(DLAEEM 5-2) of/du 5.85	D-01-060-001/ AX-007 July 86		1990				
DA								
FR								
GE								
GR								
IT								
LU								
* NL	M85/0302/ of/du 10.12.85		12.86	12.86				
* NO	MAS-402/85/B/FO/OSB/HHH/ ISO/STANAG 5000 of/du 15.4.85		N/A	No fore-cast	No fore-cast			
PO								
SP								
TU	DISISLERI, # 390 of/du 24.5.85							
UK	D/D Stan/201/11/5000 of/du 18.3.85.	Defence Standard	6.87	6.87	6.87			
US	J 5000 of/du 17.5.85.	MIL-STD-188-161	88				86	86

*See reservation overleaf/
Voir réserve au verso

RESERVATIONS

Netherlands: Implementation for air forces is not to be expected yet.

Norway: Norway reserves her right to use other standards for facsimile between national units when/if economical and/or employment aspects make it necessary.

RESERVES

Pays-Bas: La mise en service pour la force aérienne n'est pas encore prévue.

Norvège: La Norvège se réserve le droit d'utiliser d'autres normes pour le fac-similé entre les unités nationales lorsque/si des aspects économiques et/ou d'utilisation le rendent nécessaire.

NATO STANDARDIZATION AGREEMENT
(STANAG)

INTEROPERABILITY OF TACTICAL DIGITAL FACSIMILE EQUIPMENT

Annexes: A. Glossary of Facsimile Terms and Possible Equipment Configurations

B. Technical Characteristics for Interoperability of NATO Type 1 Tactical Digital Facsimile Equipment

C. Technical Characteristics for Interoperability of NATO Type 2 Tactical Digital Facsimile Equipment

Related Documents: A. MC 278
B. ACP 167(F)

INTRODUCTION

1. The use of facsimile equipment on communications links provides the advantages of minimal message preparation time, the production of a permanent paper record and transmission of original documents with authenticating signatures.

2. Analogue facsimile is widely used in meteorological applications, including reception of meteorological and oceanographic charts by military organizations. However, for general tactical purposes, analogue facsimile equipment has strictly limited use because analogue transmissions cannot easily be given adequate security protection. Only digital facsimile transmissions are capable of being given the necessary fully secure protection over standard data links and with standard cryptographic equipment.

AIM

3. The aim of this agreement is to define the technical characteristics required to ensure the interoperability of tactical digital facsimile equipment.

AGREEMENT

4. Participating nations of the North Atlantic Treaty Organization agree to use the characteristics detailed in this agreement for their tactical digital facsimile equipment.

DEFINITIONS

5. To meet the Operational Requirement and ensure interoperability, a family of two variants of facsimile equipment is required as follows:

(a) NATO Type 1. A lightweight, rugged and relatively inexpensive machine, optimised for fast transmission and receipt of documents in black and white only, over voice bandwidth channels, having error rates up to 1 in 10^3. The machine should be capable of transmitting documents up to 210 mm wide and which include, typescripts, manuscripts, line drawings, and map overlays. Resolution of the smallest typed characters and symbols in "Elite" type at 12 characters per inch (4.72 characters per cm) for documents is essential.

(b) NATO Type 2. A more elaborate machine than Type 1, which includes all the capabilities of the Type 1 machine in black and white, but which additionally is capable of transmitting and receiving documents, including maps, in several shades of grey.

IMPLEMENTATION OF THE AGREEMENT

6. This STANAG is implemented by a nation when it has issued instructions that all such equipment procured for its forces will be manufactured in accordance with the characteristics detailed in this agreement.

GLOSSARY OF FACSIMILE TERMS

OPERATIONAL MODES

The terms defined are as stated in ACP 167(F) dated August 1981 - "Glossary of Communications - Electronic Terms".

1. Broadcast Method - A method of transmitting messages or information to a number of receiving stations which make no receipt.

Interpretation for facsimile. The various pre- and post-message signals will be sent by the transmitter without acknowledgement from the receiver(s). Special procedure signals may be required for this mode.

2. Simplex Operation - Simplex operation refers to communication between two points in both directions, but not simultaneously.

Interpretation for facsimile. When required by the procedure, the receiver will respond to pre- and post-message signals after they are completed by the transmitter. When the response is completed, the transmitter is free to go ahead with the next step in the procedure. With simplex radio or two-wire circuits this will be done by reversing the direction of the circuit. With four-wire circuits separate pairs of wires may be used for transmission and response but the procedure is still sequential.

3. Half-Duplex Operation - Operating method using a circuit designed for duplex operation, but which, on account of the terminal equipment, can be operated alternately only.

Interpretation for facsimile. Even though the facsimile equipment may be able to receive and transmit, it may not be able to do so simultaneously. The procedure will be the same as for simplex operation.

4. Duplex Operation - Duplex (full-duplex) operation refers to communication between two points in both directions simultaneously.

Interpretation for facsimile. This is the case when the terminal facsimile equipment at each end is capable of full-duplex operation. The procedure will be the same as for simplex, for each direction. The two transmissions are completely independent and may be accomplished by using non-duplex equipment.

5. Net (Communications) - An organization of stations capable of direct communications on a common channel or frequency.

Tactical Communications. This is the case with combat net radio (push-to-talk). All stations on the net are capable of simplex operation but only sequentially.

Interpretation for facsimile. If one station wishes to transmit to more than one station on the net, the broadcast method is used. If there is only one receiver, the simplex method can be used.

6. Network - An organization of stations capable of inter-communication but not necessarily on the same channel.

Tactical communications. This is not a usual tactical facility. It is unlikely that exclusive facsimile communications channels or systems will be available.

Interpretation for facsimile. Depending on the facility and terminal equipment, operation could be broadcast, simplex, half-duplex or full-duplex.

EXPLANATORY NOTES TO THE FOREGOING

7. There are two aspects of facsimile communications:

(a) The actual transmission and reception of the document, sketch or picture and

(b) the transmission of procedure signals which precede or follow this.

8. Nations may adopt any of the following configurations:

(a) Transmissions capable only of broadcasting facsimile doucments. These will also send the required procedure signals.

(b) Receivers capable only of receiving facsimile broadcasts and the procedure signals.

NOTE

(a) and (b) would be capable of interoperating only in the broadcast mode.

(c) Transmitters capable of sending facsimile documents and procedure signals and receiving response procedure signals from a receiver.

(d) Receivers capable of receiving facsimile transmissions and procedure signals and sending any necessary response procedure signals to the transmitter.

NOTE

(c) and (d) could be capable of interoperating in both the simplex and broadcast mode.

(e) (c) and (d) could of course be combined in one equipment. Two such equipments could be capable of operating in any mode.

(f) If the transmitter and receiver of a combined equipment shared some internal circuits or other components they would only be capable of broadcast, simplex or half-duplex operation.

ASPECT RATIO

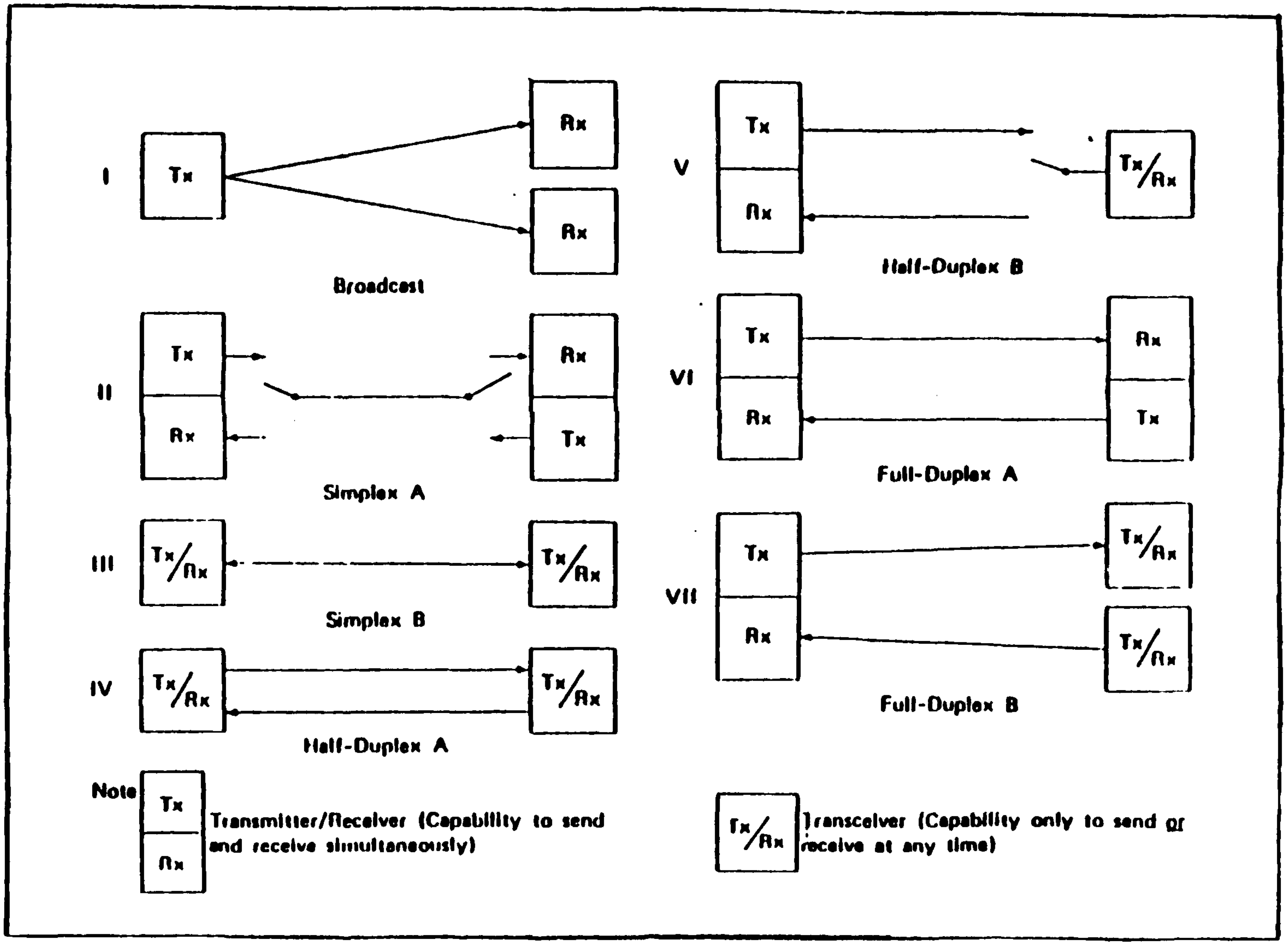
9. Aspect Ratio $= \frac{\text{PEL Height}}{\text{PEL Width}}$

$$= \frac{\text{PEL per line}}{\text{Line density X scanned line length}}$$

e.g. $\frac{\text{1728 PELs}}{\text{7.7 lines per mm x 215 mm}} = 1.044$ (aspect ratio)

STUFFING

10. Stuffing is a bit pattern transmitted with the purpose of inserting a pause in the information stream. It takes a form which will not cause the receiver to respond in a manner which conflicts with the requirements of this STANAG.



POSSIBLE EQUIPMENT CONFIGURATIONS

TECHNICAL CHARACTERISTICS FOR INTEROPERABILITY OF NATO TYPE 1 TACTICAL DIGITAL FACSIMILE EQUIPMENTS

GENERAL

1. This Annex establishes the minimum basic technical standards for interoperability of NATO Type 1 tactical digital facsimile equipment. It will apply to all equipment regardless of the types of circuits over which they will be required to operate. It is not concerned with the modems which may be required to interface with the transmission equipment.

2. Implementation of the standard will ensure that NATO Type 1 machines will be able to interoperate with each other in all mandatory modes. There may be optional secondary modes which may not be agreed to by all nations. Interoperation is considered to be satisfactory if the copy received on a machine of Nation X from a transmission of a machine of Nation Y is not significantly lower in quality than would be provided by a receiver of Nation Y's system under the same circumstances.

TRANSMISSION MODES

3. Operation includes broadcast, simplex, half-duplex and duplex as defined in Annex A. Possible equipment and communications configurations are also shown in Annex A, Appendix 1.

IMAGE PARAMETERS

4. All equipments shall be capable of interoperating to the following parameters.

(a) A definition standard of 3.85 scan lines per mm in the vertical direction.

(b) 1728 picture elements (pels) along the scan line.

(c) A scanning line length of 215 mm.

(d) Image proportions will be maintained within ± 1%.

(e) Input documents up to 215 mm wide by 1,000 mm(1) long shall be accepted. (At national prerogative, machines may accept wider documents although only 215 mm wide will be transmitted.)

(f) Scanning shall be from left to right and top to bottom.

---

(1) Docuemnts up to 1000 mm long must be transmitted and received in one pass without interruption. The end of a document transmission signal "Return to Control" can be sent for any length up to 1000 mm long.

SCANNED LINE TRANSMISSION TIME

5. The cumulative transmission time of any total coded scanned line, consisting of the sum of DATA bits, plus FILL bits, plus EOL bits, plus (when FEC is used) any inserted check bits shall not be less than 20 milliseconds.

CONTRAST LEVELS

6. Only two contrast levels, black and white, shall be transmitted.

ELECTRICAL INTERFACE

7. Electrical characteristics of interfaces shall be as required by national standards.

DATA TRANSMISSION RATES

8. Equipment must be able to interoperate at 2.4 and 16 Kilobits per second and at other rates between 1.2 and 16 Kbts as may be agreed to in NATO. The data transmission rate is selected by operators in accordance with the standard operating procedures for interoperation. The facsimile equipment will derive its clock rate from the communications equipment to which it is connected.

IMAGE DATA CODING

9. The choice of the following three forms of data coding shall be provided:

(a) Uncompressed.

(b) Compressed.

(c) Compressed as (b) with forward error correction (FEC).

These coding schemes are fully described in Appendix 1.

10. The required mode is selected by the operator at the transmitting facsimile equipment. The transmitter will automatically, using the premessage protocol, programme the receiving machine to the appropriate mode and coding form.

REQUIRED SIGNALS FOR INTEROPERABILITY

11. The signals listed below are mandatory. Other signals may be required by national procedures.

(a) Signals extracted from the V.24 Recommendations of the CCITT Orange Book:

(1) Signal Common Return (102);

(2) Transmitted Data (103);

(3) Received Data (104);

(4) Request to Send (105);

(5) Ready for Sending (106);

(6) Data Set Ready (107);

(7) Data Terminal Ready (108/2);

(8) Transmitter Signal Element Timing from DCE (114), and;

(9) Receiver Signal Element Timing from DCE (115).

(b) Loss of Facsimile Synchronization Signal.

(1) The receiver shall be capable of detecting loss of synchronization.

(2) At any time following detection of the first synchronization signal, the receiver shall declare a loss of synchronization if a synchronization code has not been detected within a time-out period. This period shall be sufficiently long to preclude false declaration of synchronization.

(3) The signal indicating this loss shall be an "on" state, as defined by national electrical interface standards, applied to the Loss of Synchronization Interchange Circuit.

12. A protective ground is required.

SIGNALLING PROTOCOLS

13. The signalling protocol includes both the pre-message procedure and the post-message procedure. Details of the protocol signals and timing are in Appendix 2.

OPTIONS

14. In addition to the above mandatory parameters, the following options are defined:

(a) Optional Image Parameters - Appendix 3

(b) Handshake Protocols - Appendix 4, and

(c) Extended Protocols - Appendix 5.

15. If optional parameters or an optional mode is to be used, this is selected by the operator at the transmitting terminal. Receiving the appropriate protocol should cause the receiver to adopt the required mode of operation.

16. In a handshake mode, if the receiving station cannot adopt the mode offered, it will return the appropriate signal to the transmitter. The transmitter then may return to standby or the operator may try another mode or make other arrangements by voice.

IMAGE DATA CODING SCHEMES

INTRODUCTION

1. Figure 1 shows a simplified block diagram of the encoder. Three output modes shall be available:

(a) Uncompressed facsimile data with line synchronization codes added.

(b) Compressed facsimile data using a one-dimensional run-length code. (See Table 1).

(c) Compressed as in (b) with the addition of Forward Error Correction (FEC) using a BCH code and bit interleaving buffer.

2. Figure 2 shows a simplified block diagram of the complementary decoder at the receiver.

3. It is necessary that the scheme selected for a given transmission be signalled to the receiver. This signalling protocol is described in Appendix 2.

4. Details of each transmission mode are given below.

UNCOMPRESSED

5. At data output A (Figure 1), a document shall be transmitted pel (picture element) by pel, with logic 1 representing black. Each line of the output data shall consist of a synchronization code followed by 1728 pels. This synchronization code consists of a sequence of two So code words where:

So = 111100010011010
first transmitted bit

Therefore the line format is

So	So	1728 pels

COMPRESSED

6. At data output B (Figure 1) facsimile data is transmitted after compression by a redundancy reduction algorithm. This is a one-dimensional run-length scheme as follows:

(a) DATA

(1) A line of data is composed of a series of variable length code words. Each code word represents a run-length of either all white or all black. White runs and black runs alternate. A total of 1728 picture elements represent one horizontal scanning line of the document of standard A4 size.

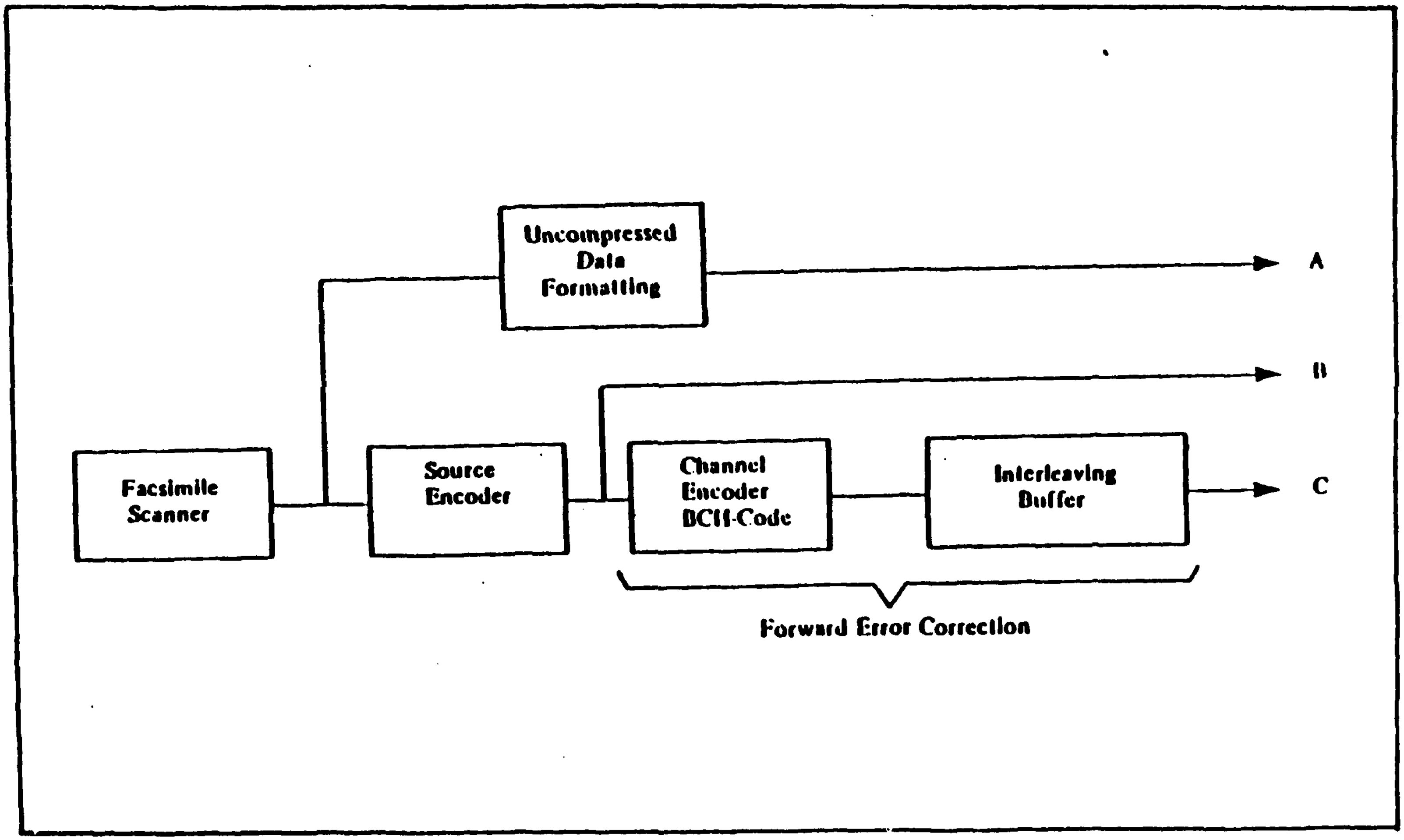


FIGURE 1 - Block Diagram of the Encoder

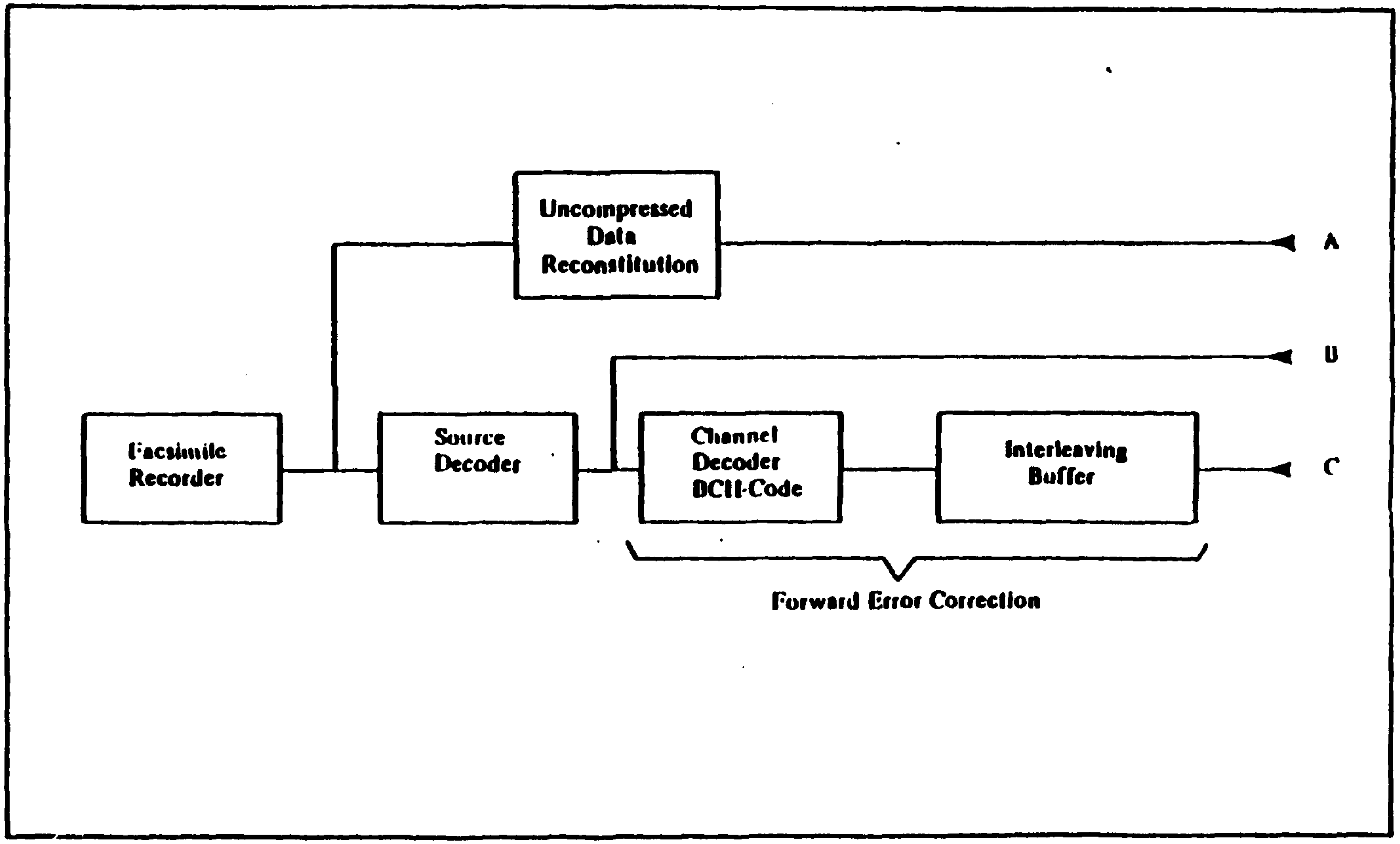


FIGURE 2 - Block Diagram of the decoder

In order to insure that the receiver maintains colour synchronization, all DATA lines will begin with a white run-length code word. If the actual scanning line begins with a black run, a white run-length of zero will be sent. Black or white run-lengths, up to a maximum length of one scanning line (1728 pels) are defined by the code words in Tables 1 and 2. The code words are of two types: Terminating Code words and Make-Up Code words. Each run-length is represented by either one Terminating Code word or one Make-Up Code word followed by a Terminating Code word.

(2) Run-lengths in the range of 0 to 63 pels are encoded with their appropriate Terminating Code word. Note that there is a different list of code words for black and white runs.

(3) Run-lengths in the range of 64 to 1728 pels are encoded first by the Make-Up Code word representing the run-length which is equal to or shorter than that required. This is then followed by the Terminating Code word representing the difference between the required run-length and the run-length represented by the Make-Up Code.

(b) End-of-Line (EOL) This code word follows each line of DATA. It is a unique code word that can never be found within a valid line of DATA. Therefore, re-synchronization after an error burst is possible. In addition, this signal will also be sent prior to the first DATA line of a page:

EOL Format: 000000000001

(c) FILL A pause may be placed in the message flow by transmitting FILL. FILL may be inserted between a line of DATA and an EOL, but never within a line of DATA. FILL must be added to insure that the transmission time of each total coded scan line is not less than the minimum defined in this Annex. At data rates of 2.4 Kb/s and above, the maximum transmission time of any total coded scan line should be less than 5 seconds. After this the receiver may disconnect.

At data rates below 2.4 Kb/s, the maximum line transmission time is not limited by this standard.

FILL format: a variable length string of 0s.

Table 1: Terminating Codes

NOTE: These codes are identical to those of CCITT Recommendation T.4 of the Yellow Book. Any future changes to this recommendation will have to be examined for adoption irto this STANAG.

White Run Length	**Code Word**	**Black Run Length**	**Code Word**
0	00110101	0	0000110111
1	000111	1	010
2	0111	2	11
3	1000	3	10
4	1011	4	011
5	1100	5	0011
6	1110	6	0010
7	1111	7	00011
8	10011	8	000101
9	10100	9	000100
10	00111	10	0000100
11	01000	11	0000101
12	001000	12	0000111
13	000011	13	00000100
14	110100	14	00000111
15	110101	15	000011000
16	101010	16	0000010111
17	101011	17	0000011000
18	0100111	18	0000001000
19	0001100	19	00001100111
20	0001000	20	00001101000
21	0010111	21	00001101100
22	0000011	22	00000110111
23	0000100	23	00000101000
24	0101000	24	00000010111
25	0101011	25	00000011000
26	0010011	26	000011001010
27	0100100	27	000011001011
28	0011000	28	000011001100
29	00000010	29	000011001101
30	00000011	30	000001101000

Table 1 (cont.): Terminating Codes

White Run Length	Code Word	Black Run Length	Code Word
31	00011010	31	000001101001
32	00011011	32	000001101010
33	00010010	33	000001101011
34	00010011	34	000011010010
35	00010100	35	000011010011
36	00010101	36	000011010100
37	00010110	37	000011010101
38	00010111	38	000011010110
39	00101000	39	000011010111
40	00101001	40	000001101100
41	00101010	41	000001101101
42	00101011	42	000011011010
43	00101100	43	000011011011
44	00101101	44	000001010100
45	00000100	45	000001010101
46	00000101	46	000001010110
47	00001010	47	000001010111
48	00001011	48	000001100100
49	01010010	49	000001100101
50	01010011	50	000001010010
51	01010100	51	000001010011
52	01010101	52	000000100100
53	00100100	53	000000110111
54	00100101	54	000000111000
55	01011000	55	000000100111
56	01011001	56	000000101000
57	01011010	57	000001011000
58	01011011	58	000001011001
59	01001010	59	000000101011
60	01001011	60	000000101100
61	00110010	61	000001011010
62	00110011	62	000001100110
63	00110100	63	000001100111

Table 2: Make-Up Codes

NOTE: These codes are identical to those of CCITT Recommendation T.4 of the Yellow Book. Any future changes to this recommendation will have to be examined for adoption into this STANAG.

White Run Length	Code Word	Black Run Length	Code Word
64	11011	64	0000001111
128	10010	128	000011001000
192	010111	192	000011001001
256	0110111	256	000001011011
320	00110110	320	000000110011
384	00110111	384	000000110100
448	01100100	448	000000110101
512	01100101	512	0000001101100
576	01101000	576	0000001101101
640	01100111	640	0000001001010
704	011001100	704	0000001001011
768	011001101	768	0000001001100
832	011010010	832	0000001001101
896	011010011	896	0000001110010
960	011010100	960	0000001110011
1024	011010101	1024	0000001110100
1088	011010110	1088	0000001110101
1152	011010111	1152	0000001110110
1216	011011000	1216	0000001110111
1280	011011001	1280	0000001010010
1344	011011010	1344	0000001010011
1408	011011011	1408	0000001010100
1472	010011000	1472	0000001010101
1536	010011001	1536	0000001011010
1600	010011010	1600	0000001011011
1664	011000	1664	0000001100100
1728	010011011	1728	0000001100101
EOL	000000000001	EOL	000000000001

(d) Return to control (RTC) The end of a document transmission is indicated by sending a minimum of two RTCs. Each RTC shall consist of six consecutive EOLs. Following the RTC signals, the transmitter will send the post-message commands.

RTC Format: 000000000001 ____________ 000000000001
EOL1 EOL6

To further clarify the relationship of the signals defined herein, Figures 3 and 4 are offered. Figure 3 shows several scan lines of data starting at the beginning of a transmitted page. Figure 4 shows the last line of a page.

COMPRESSED WITH FEC

7. At data output C (Figure 1) compressed facsimile data has been further processed by a channel coder and bit interleaving buffer. The channel coder uses a forward error correcting code scheme (BCH code) with the capability of correcting two bit errors per block. Table 3 lists the details of the BCH code.

8. In Figure 5 a proposal for an implementation of the BCH-Encoder is given using a feedback-shift-register. The length of the feeback-shift-register is 12 bits according to the generator polynomial. During one cycle of 63 clocks one block of data is sent at the output of BCH-Encoder. At the beginning of the cycle the contents of the feedback-shift-register (r_0, ..., r_{11}) is equal to 0. Initially 51 information bits are transmitted from the data input to the output.

9. At the same time the information bits are running into the feedback loop of the shift register (C_0= 1). After 51 clocks the contents of the feedback-shift-register (r_0, ..., r_{11}) is transmitted with 12 clocks C_0= 0. These 12 bits are the check bits for the block of 63 data bits. After every cycle of 63 clocks the contents of the feedback-shift-register should be and will be zero (r_0, ..., r_{11}= 0). Then the next 51 inforamtion bits can be encoded.

10. In Figure 6 a proposal for implementation of the BCH-Decoder is given. The BCH-Decoder uses the same feedback-shift-register as the BCH-Encoder, plus 63 bit-buffer-memory (shift-register) and a network. One complete decoding cycle consists of 126 clocks (2 x 63). At the beginning of every cycle the contents of the feedback-shift-register (r_0, ..., r_{11}) must be equal to 0. The clock appears at the same time to the feedback-shift-register and the 63 bit-buffer-memory. During the first 63 clocks the block of 63 data bits are written into the 63 bit-buffer-memory and at the same time run into the feedback-loop of the shift-register (C_1= 0). During the next

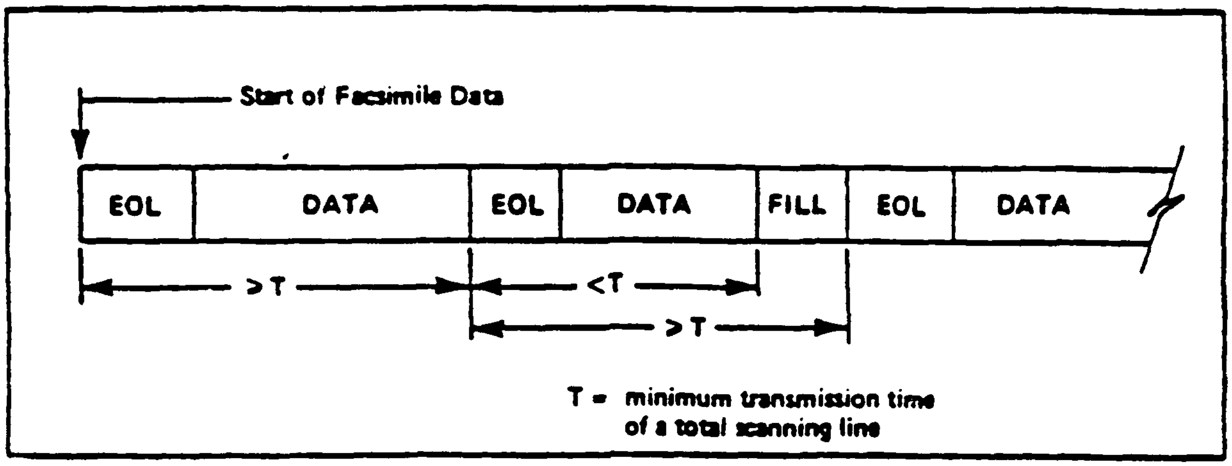


Fig. 3: Example of an encoded scan line, starting at the beginning of a page.

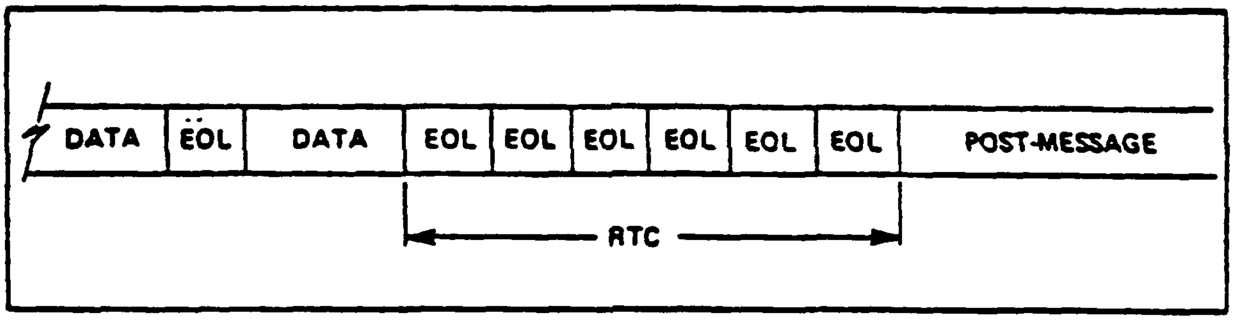


Fig. 4: Example of an encoded scan line for the last scan line of a page.

Block length	63 bits
Information bits	51 bits
Check bits	12 bits
Error correcting capability	2 bits
Redundancy	23.5 %
Generator polynomial	$G = x^{12} \oplus x^{10} \oplus x^{8} \oplus x^{5} \oplus x^{4} \oplus x^{3} \oplus 1$

Table 3: Parameters of the BCH-Code

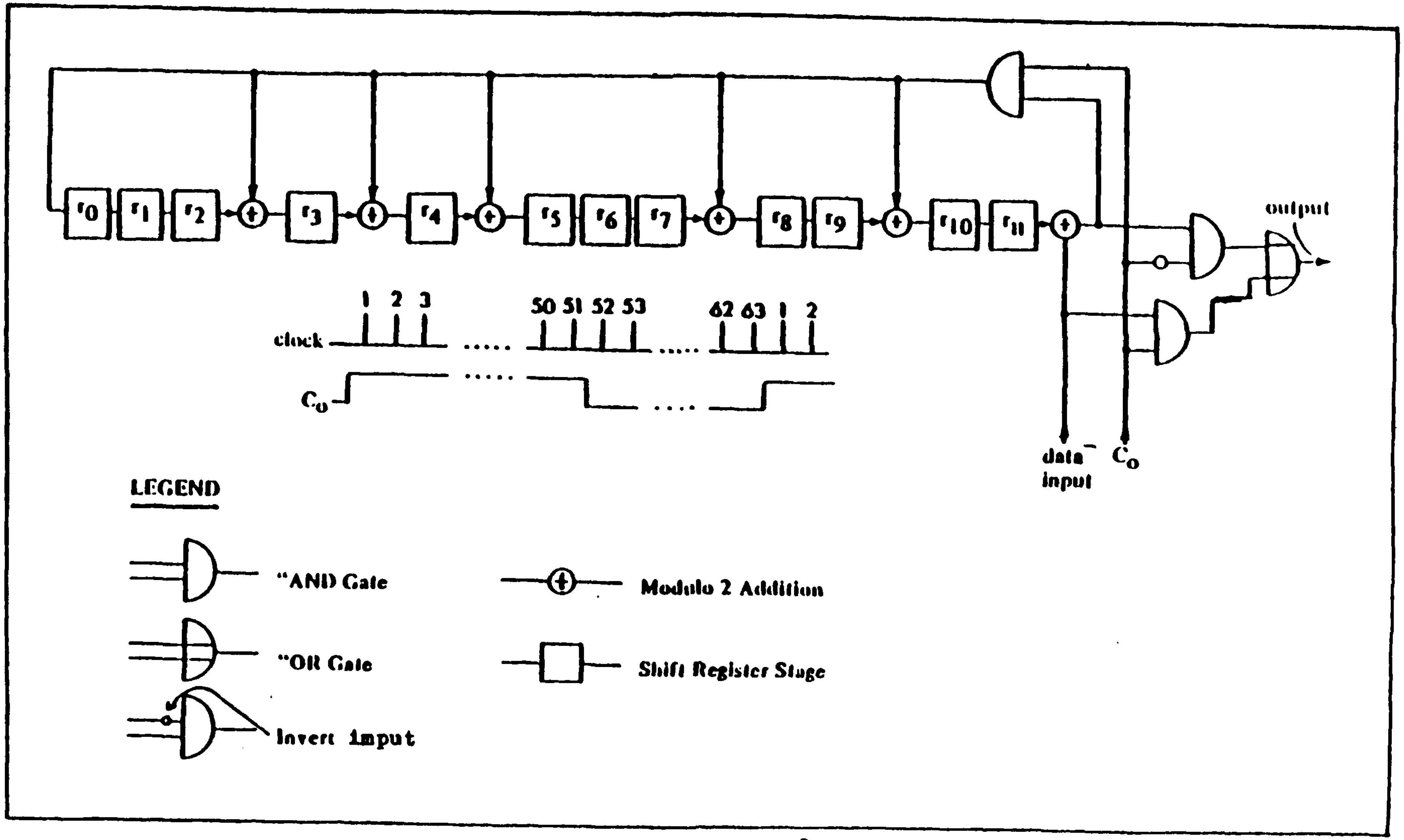


FIGURE 5 - BCH-ENCODER

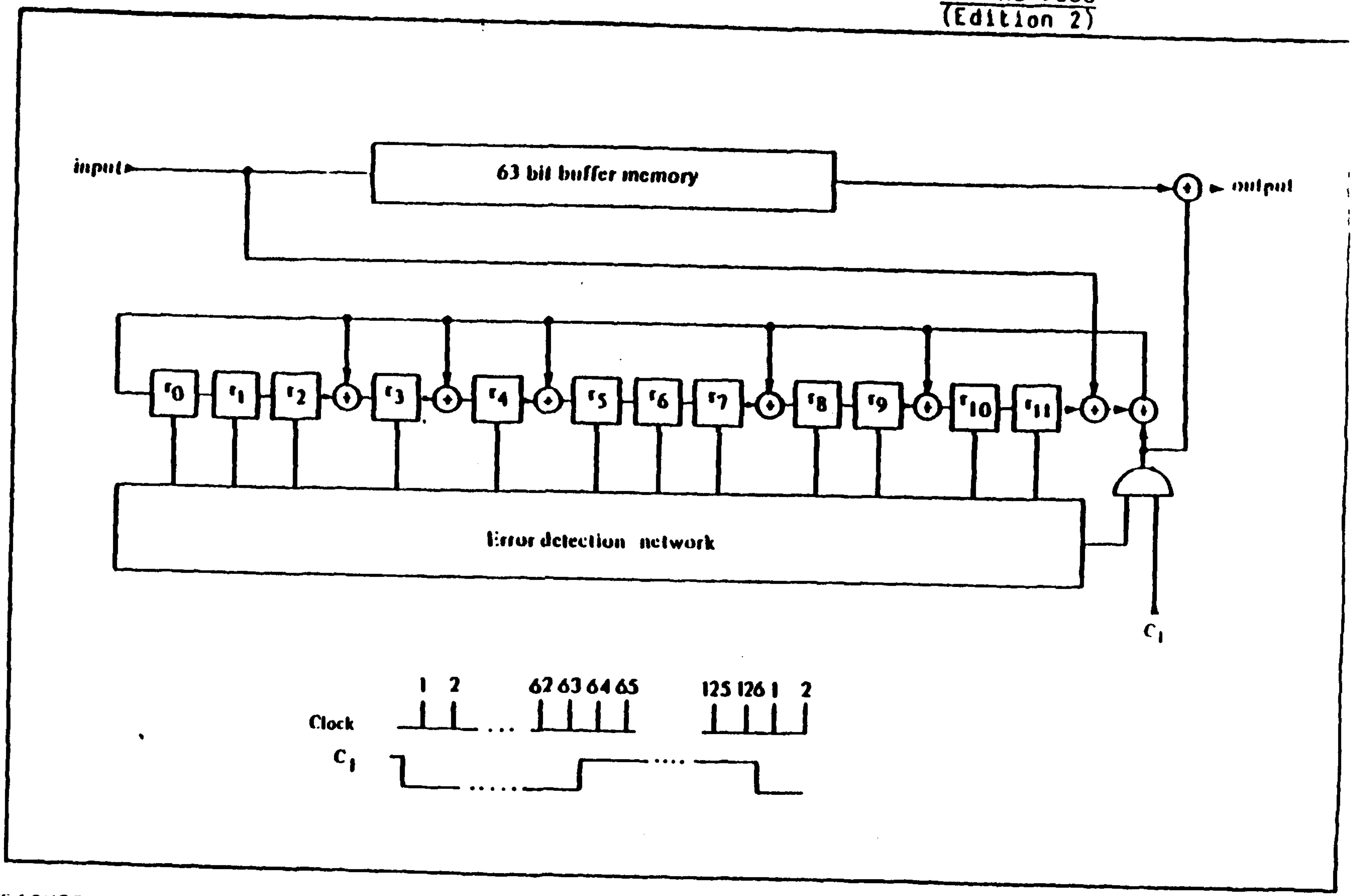


FIGURE 6 - BCH-DECODER

63 clocks (C_1= 1) the transmission bit errors are corrected, if there are any. The contents of the feedback-shift-register (r_0, ..., r_{11}) is analysed after every clock by the error detection network. If the network detects any one of the 12 bit patterns (syndromes) listed in Table 4 as the contents of the feedback-shift-register, then the position of a transmission bit error is found to be at the output of the 63 bit-buffer-memory. At that time the output of the network will correct the transmission bit error by sending a 1 to the mod 2-adder at the output of the 63 bit-buffer-memory. Note that only the first 51 bits are information bits. After every cycle of 126 clocks the feedback-shift-register must be reset to zero (r_0, ..., $r_{11} = 0$) and the next block of 63 data bits can be decoded.

11. Interleaving Buffer. For reasons of improving the error correcting capability of the channel encoder especially considering transmission bit errors clustered in bursts, an interleaving buffer is used.

(a) The buffersize is N x W = 63 x 5 = 315 bits. Figure 7 shows the interleaving buffer at the transmitting side. Data input is line-by-line, data output is column-by-column. So, the data input sequence is:

D_0, D_1, D_2, ... D_{313}, D_{314}.

(b) Accordingly the data output sequence is:

D_0, D_{63}, D_{126}, D_{189}, D_{252}, D_1, D_{64}, ...

(c) At the receiving side the data input and data output sequence is the reverse of this (see Figure 8).

12. Synchronization. If the BCH-Coder and interleaving buffer are used, then a synchronization of both BCH-Coder and interleaving buffer is necessary between transmitter and receiver before starting facsimile transmission.

(a) The FEC Control block is the synchronization SOM sequence when the BCH-Coder and interleaving buffer are used: Figure 9 illustrates the format of the synchronization SOM sequency. There are three possible points to achieve block synchronization.

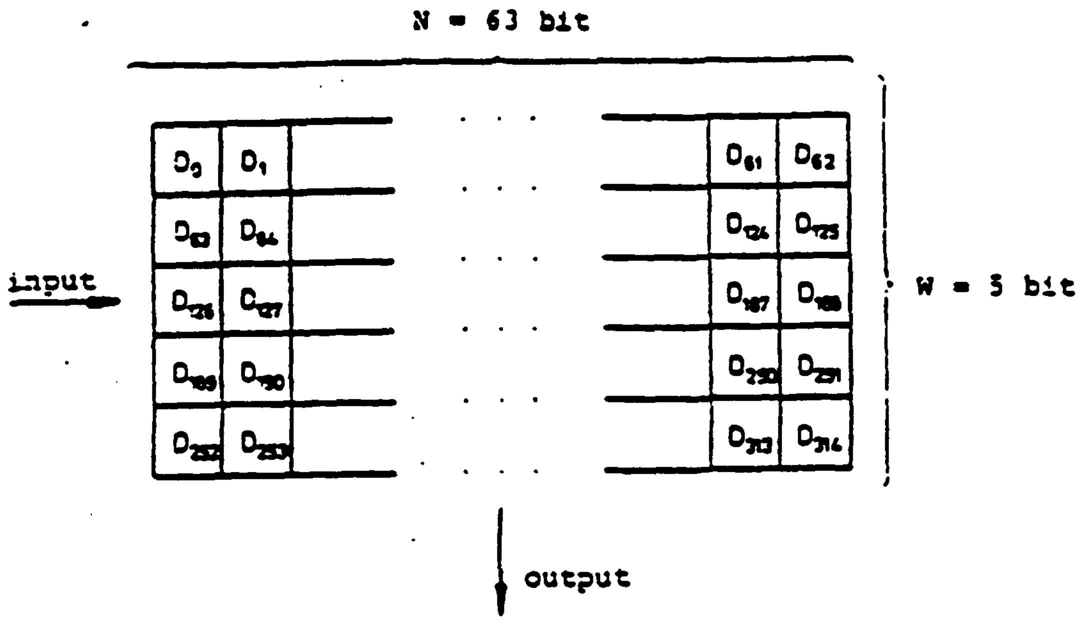
(b) The synchronization SOM sequence is sent by the transmitter without using BCH-Encoder and interleaving buffer; after the synchronization SOM sequence immediately the encoded facsimile data are sent using the BCH-Encoder and interleaving buffer.

	S_{11}	S_{10}	S_9	S_8	S_7	S_6	S_5	S_4	S_3	S_2	S_1	S_0
R_1	1	0	0	0	0	0	0	0	0	0	0	0
R_2	1	1	0	0	0	0	0	0	0	0	0	0
R_3	1	0	1	0	0	0	0	0	0	0	0	0
R_4	1	0	0	1	0	0	0	0	0	0	0	0
R_5	1	0	0	0	1	0	0	0	0	0	0	0
R_6	1	0	0	0	0	1	0	0	0	0	0	0
R_7	1	0	0	0	0	0	1	0	0	0	0	0
R_8	1	0	0	0	0	0	0	1	0	0	0	0
R_9	1	0	0	0	0	0	0	0	1	0	0	0
R_{10}	1	0	0	0	0	0	0	0	0	1	0	0
R_{11}	1	0	0	0	0	0	0	0	0	0	1	0
R_{12}	1	0	0	0	0	0	0	0	0	0	0	1
R_{13}	0	0	1	0	1	0	0	1	1	1	0	0
R_{14}	1	1	0	1	0	1	0	0	1	1	1	0
R_{15}	1	0	1	0	1	0	1	0	0	1	1	1
R_{16}	0	0	1	1	1	1	0	0	1	1	1	1
R_{17}	0	1	1	1	0	1	1	1	1	0	1	1
R_{18}	0	1	0	1	0	0	1	0	0	0	0	1
R_{19}	0	1	0	0	0	0	0	0	1	1	0	0
R_{20}	1	1	1	0	0	0	0	0	0	1	1	0
R_{21}	1	0	1	1	0	0	0	0	0	0	1	1
R_{22}	0	0	1	1	0	0	0	1	1	1	0	1
R_{23}	0	1	1	1	0	0	0	1	0	0	1	0
R_{24}	1	1	1	1	1	0	0	0	1	0	0	1
R_{25}	0	0	0	1	0	1	0	1	1	0	0	0
R_{26}	1	1	0	0	1	0	1	0	1	1	0	0
R_{27}	1	0	1	0	0	1	0	1	0	1	1	0
R_{28}	1	0	0	1	0	0	1	0	1	0	1	1
R_{29}	0	0	1	0	0	0	0	0	1	0	0	1
R_{30}	0	1	1	1	1	0	0	1	1	0	0	0
R_{31}	1	1	1	1	1	1	0	0	1	1	0	0
R_{32}	1	0	1	1	1	1	1	0	0	1	1	0

Table 4.1: Syndromes of the BCH-Decoder

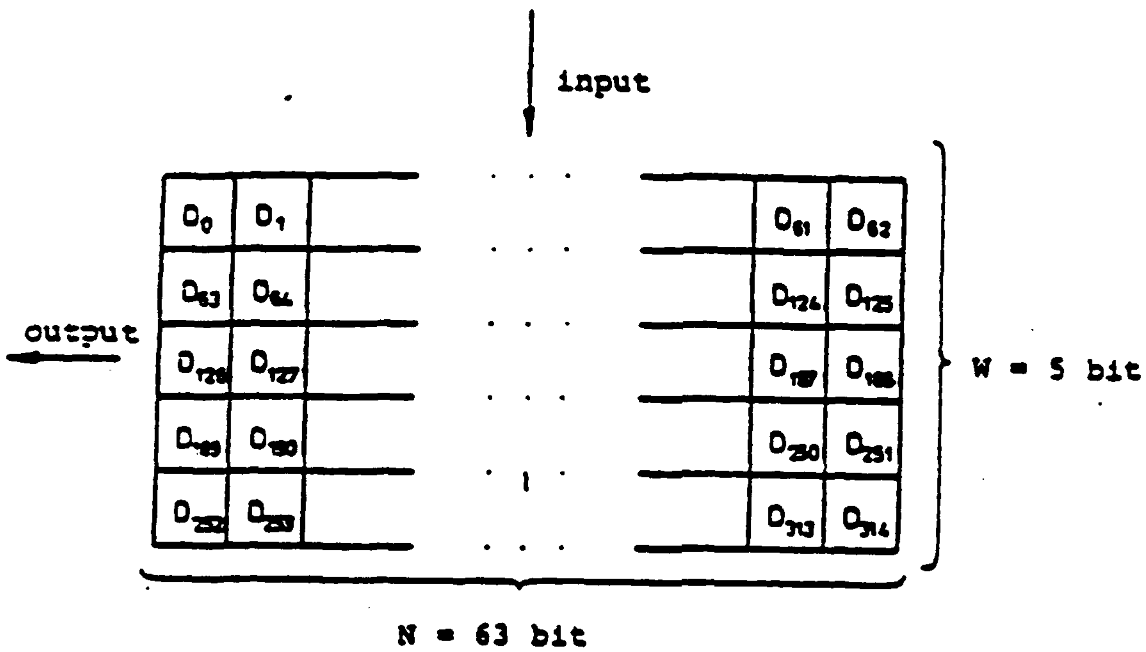
	z_{11}	z_{10}	z_9	z_8	z_7	z_6	z_5	z_4	z_3	z_2	z_1	z_0
R_{33}	1	0	0	1	1	1	1	1	0	0	1	1
R_{34}	0	0	1	0	0	1	1	0	0	1	0	1
R_{35}	0	1	1	1	1	0	1	0	1	1	1	0
R_{36}	1	1	1	1	1	1	0	1	0	1	1	1
R_{37}	0	0	0	1	0	1	1	1	0	1	1	1
R_{38}	0	1	1	0	0	0	1	0	0	1	1	1
R_{39}	0	1	0	1	1	0	0	0	1	1	1	1
R_{40}	0	1	0	0	0	1	0	1	1	0	1	1
R_{41}	0	1	0	0	1	0	1	1	0	0	0	1
R_{42}	0	1	0	0	1	1	0	0	0	1	0	0
R_{43}	1	1	1	0	0	1	1	0	0	0	1	0
R_{44}	1	0	1	1	0	0	1	1	0	0	0	1
R_{45}	0	0	1	1	0	0	0	0	0	1	0	0
R_{46}	1	1	0	1	1	0	0	0	0	0	1	0
R_{47}	1	0	1	0	1	1	0	0	0	0	0	1
R_{48}	0	0	1	1	1	1	1	1	1	1	0	0
R_{49}	1	1	0	1	1	1	1	1	1	1	1	0
R_{50}	1	0	1	0	1	1	1	1	1	1	1	1
R_{51}	0	0	1	1	1	1	1	0	0	0	1	1
R_{52}	0	1	1	1	0	1	1	0	1	1	0	1
R_{53}	0	1	0	1	0	0	1	0	1	0	1	0
R_{54}	1	1	1	0	1	0	0	1	0	1	0	1
R_{55}	0	0	0	1	1	1	0	1	0	1	1	0
R_{56}	1	1	0	0	1	1	1	0	1	0	1	1
R_{57}	0	0	0	0	1	1	1	0	1	0	0	1
R_{58}	0	1	1	0	1	1	1	0	1	0	0	0
R_{59}	1	1	1	1	0	1	1	1	0	1	0	0
R_{60}	1	0	1	1	1	0	1	1	1	0	1	0
R_{61}	1	0	0	1	1	1	0	1	1	1	0	1
R_{62}	0	0	1	0	0	1	1	1	0	0	1	0
R_{63}	1	1	0	1	0	0	1	1	1	0	0	1

Table 4.2: Syndromes of the BCH-Decoder



Input sequence : line by line
$D_0, D_1, D_2, \ldots, D_{313}, D_{314}$
Output sequence : column by column
$D_0, D_{63}, D_{126}, D_{189}, D_{252}, D_1, D_{64}, \ldots$

FIGURE 7: Interleaving buffer at the transmitter



Input sequence : column by column

$D_0, D_{63}, D_{126}, D_{189}, D_{252}, D_1, D_{64}, \ldots$

Output sequence : line by line

$D_0, D_1, D_2, \ldots, D_{313}, D_{314}$

FIGURE 8: Interleaving buffer at the receiver

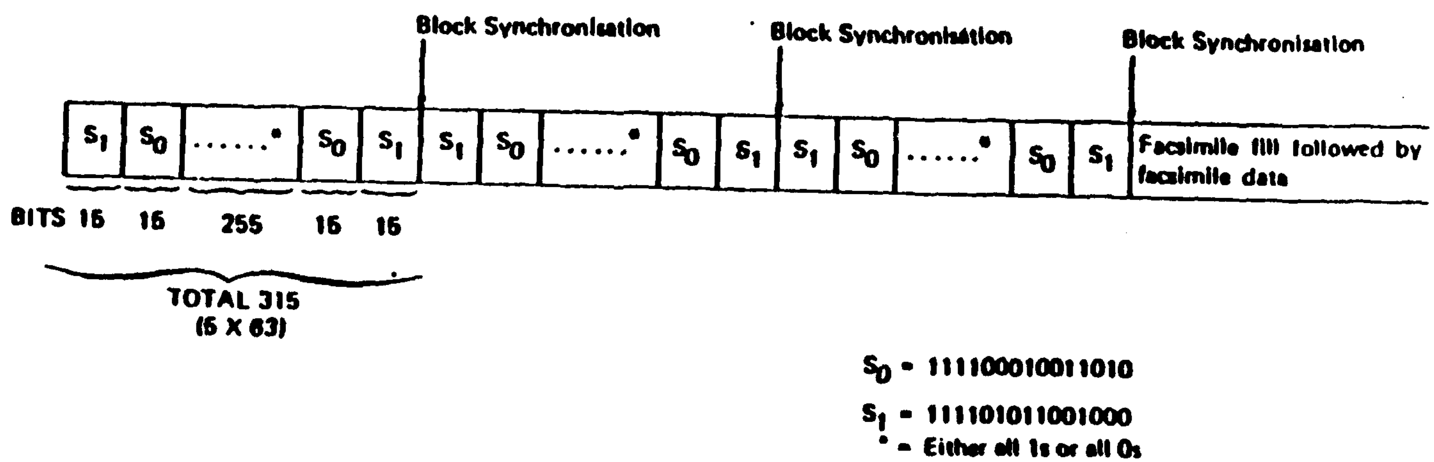


FIGURE 9: Synchronisation SOM sequences for BCH-Coder and Interleaving buffer
(See Signalling Protocol, Annex A; Appendix 2)

B-1-17

(c) At the receiver the incoming data stream is monitored bit-by-bit without using the interleaving buffer and BCH-Decoder. If any one of the synchronization SOMs (255 counts) is detected then BCH interleaving are used and the interleaving buffer and BCH-Decoder are synchronized. After the detection of any block synchronization point, incoming data pass through the interleaving buffer and BCH-Decoder to the Source Decoder.

SIGNALLING PROTOCOL FOR THE NATO MANDATORY MODE

INTRODUCTION

1. The operating mode parameters selected for each transmission are signalled to the receiver using Start of Message (SOM) frames and the termination of the facsimile transmission is signalled by an End of Message (EOM) sequence.

2. The protocol signals have been specifically designed to provide extremely high assurance of correct receiver operation (automatic start, mode setup and automatic stop) in error environments as high as 10^{-2} bit error rate (BER). This means that a return acknowledgement is not necessary for the mandatory modes, which simplifies operation.

3. The design of the SOM allows for optional or alternative modes of operation which are covered in Appendix 3.

PROTOCOL SIGNAL DESCRIPTION

4. Synchronization Code Words

(a) Two special synchronization code words are used, in various combinations, to generate all protocol requirements. The code words are designated S_0 and S_1. Each code word is made up of a 15-bit pseudo-random noise (PN) sequence as follows:

S_0: 111100010011010

↑ first transmitted bit

S_1: 111101011001000

↑ first transmitted bit

(b) If either of these PN sequences is compared, bit-by-bit with any cyclical shift of itself, the number of agreements differs from the number of disagreements by one, except at the auto-correlation peak where there are 15 agreements. Consequently, the correlation improvement for exact synchronization is 15:1 for noise-free operation and is reduced by one for every bit perturbed by noise. A significant correlation improvement is achieved therefore, even in extremely noisy environments and detection of the synchronization sequence is assured.

(c) The composition of the protocol elements in terms of the synchronization code words is shown in Table 1. This lists the probability of detection, PD, of each protocol element in a noise environment of 10^{-2} BER. All elements have detection probabilities in excess of 99.99% in this environment.

Protocol Element	Composition	P_D @ 10^{-2} BER	Transmissions Required	Detections Required
SOM	S_1 S_0 X S_0 S_1	0.999945	3	1
EOM	S_1	0.99995	16 minimum	4 in sequence

Table 1 - Protocol Elements

5. Start of Message (SOM). Each SOM frame consists of two pairs of synchronization code words, S_0 and S_1, separated by an interval.

SOM frame format:

S_1	S_0	X clock periods	S_0	S_1

The number of clock periods (X) transmitted during the interval between the two pairs of code words indicates the operating mode. The data bit corresponding to each of these clock periods shall be logic 1. The four values of X which denote the mandatory interoperability modes are shown in Table 2 along with the corresponding 8 bit binary designators.

SOM TYPE	MODE INDICATED	NUMBER OF CLOCK PERIODS (X)	BINARY DESIGNATOR 7	6	5	4	3	2	1	0
COMMAND	COMPRESSED	9	0	0	0	0	1	0	0	1
	UNCOMPRESSED	41	0	0	1	0	1	0	0	1
FEC CONTROL	FEC NOT USED	254	1	1	1	1	1	1	1	0
	FEC USED	255	1	1	1	1	1	1	1	1

Table 2 - Values of X for Mandatory Interoperability Modes

In order to achieve the high detection probabilities given in 4(c), three concatenated SOM frames are transmitted but detection of any one frame is sufficient.

The use of these signals in the mandatory modes is described in paragraphs 7, 8 and 9, Signalling Sequence and Timing.

SOM frames using other values of X are used in the optional modes and these are described in Appendix 4, Protocols for Optional Modes.

6. End of Message (EOM). EOM consists of at least 16 S_1 codewords transmitted in sequence. When four consecutive S_1 codewords ahve been detected, EOM is declared.

SIGNALLING SEQUENCE AND TIMING

7. Compressed, FEC not used

(a) Figure 1 illustrates this mode.

(b) At the start of a document transmission, a short pattern of data may be sent for the purpose of establishing the Data Channel (modem training, encryption synchronization, etc.). No constraint is placed upon the duration of this phase but the data transmitted should conform with the definition of STUFFING (Annex A paragraph 10).

(c) With the Data Communication Channel established, the signalling sequence begins with at least 16 inverted S_1 codewords. This enables the receiver to correct a channel inversion.

(d) Three COMMAND SOM frames with an X value of 9 are then sent followed by three FEC control SOM frames with an X value of 254 signifying that FEC will not be used. Stuffing may be inserted, as convenient, before and/or after the FEC control SOM frames but the facsimile data, starting with an EOL codeword, shall start no less than two seconds and no more than three seconds after the end of the third Command SOM frame.

(e) At the end of the document, the facsimile data system ends with at least two RTC Signals. Following RTC, an EOM signifies the end of the current transmission. Stuffing may be inserted as required between RTC and EOM.

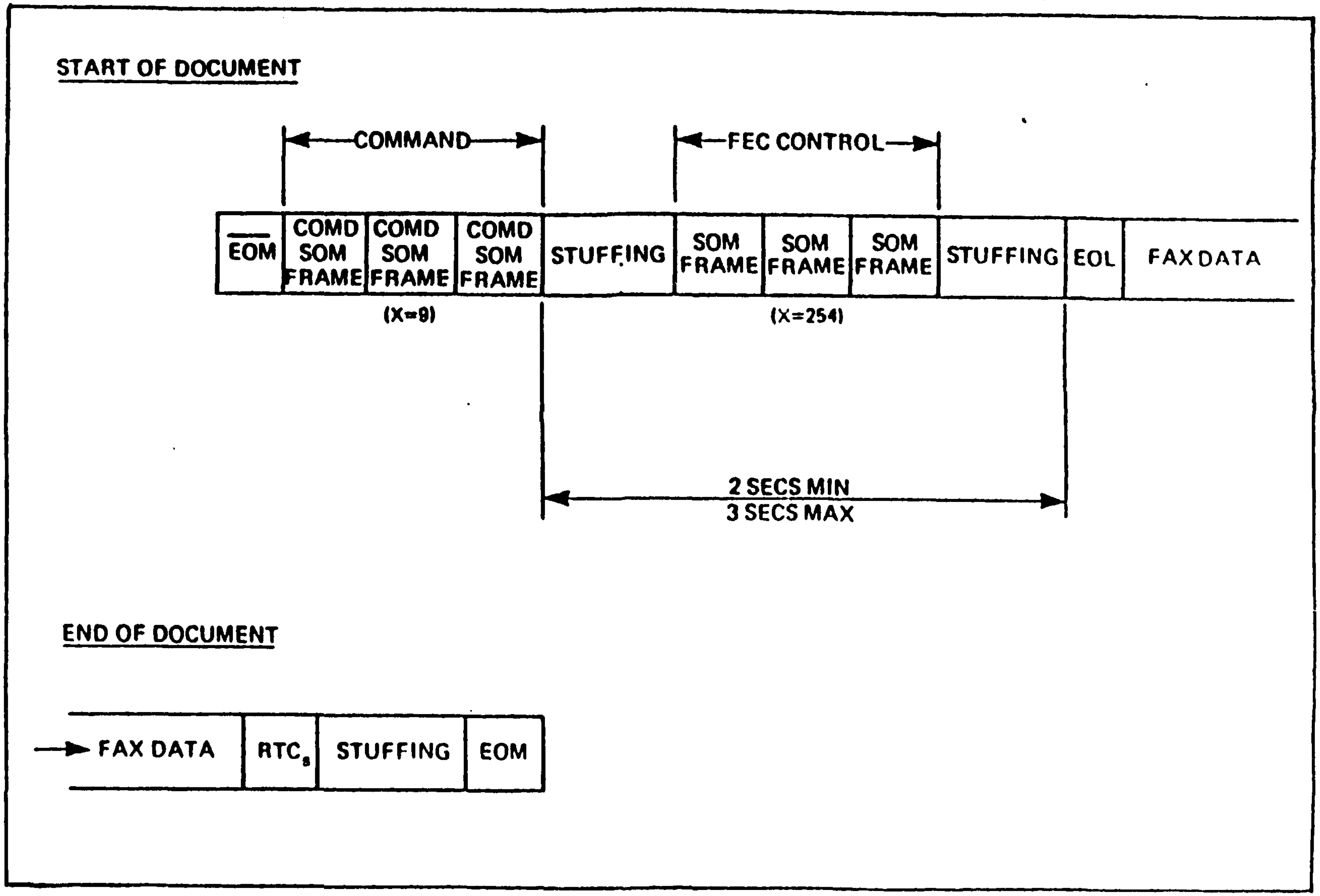


FIGURE 1 - SIGNAL TIMING, COMPRESSED MODE, FEC NOT USED

8. Compressed, FEC used

(a) Figure 2 illustrates this mode.

(b) The Data Communication Channel is established as described in Paragraph 7(b).

(c) Inverted S_1, codewords are sent as defined in Paragraph 7(c).

(d) Three COMMAND SOM frames with an X value of 9 are then sent followed by three FEC control SOM frames with an X value of 255 to indicate FEC is used and to synchronize the FEC system. The insertion of and the timing of the start of facsimile data shall be as in Paragraph 7(d).

(e) At the end of the document, the facsimile data end with at least two RTC signals. To allow freedom of implementation, EOM shall be sent both before and after the end of FEC coding. To ensure that the first EOM can be correctly decoded, the FEC block containing the final bit must be transmitted in full. Stuffing or fill bits may be inserted as required between RTC and EOM. The second EOM (outside of FEC) shall not commence earlier than 500 milliseconds after the end of the FEC block containing the final bit of RTC. Further signalling may then commence immediately.

9. Uncompressed

(a) Figure 3 illustrates this mode.

(b) The Data Communication Channel is established as in Paragraph 7(b).

(c) Inverted S_1 codewords are sent as defined in Paragraph 7(c).

(d) Three COMMAND SOM frames with an X value of 41 are then sent. Facsimile data shall follow no less than two seconds and no more than three seconds after the end of the last COMMAND SOM.

(e) At the end of the document, the facsimile data stream is terminated by two seconds of S_1 codewords. Further signalling may start immediately.

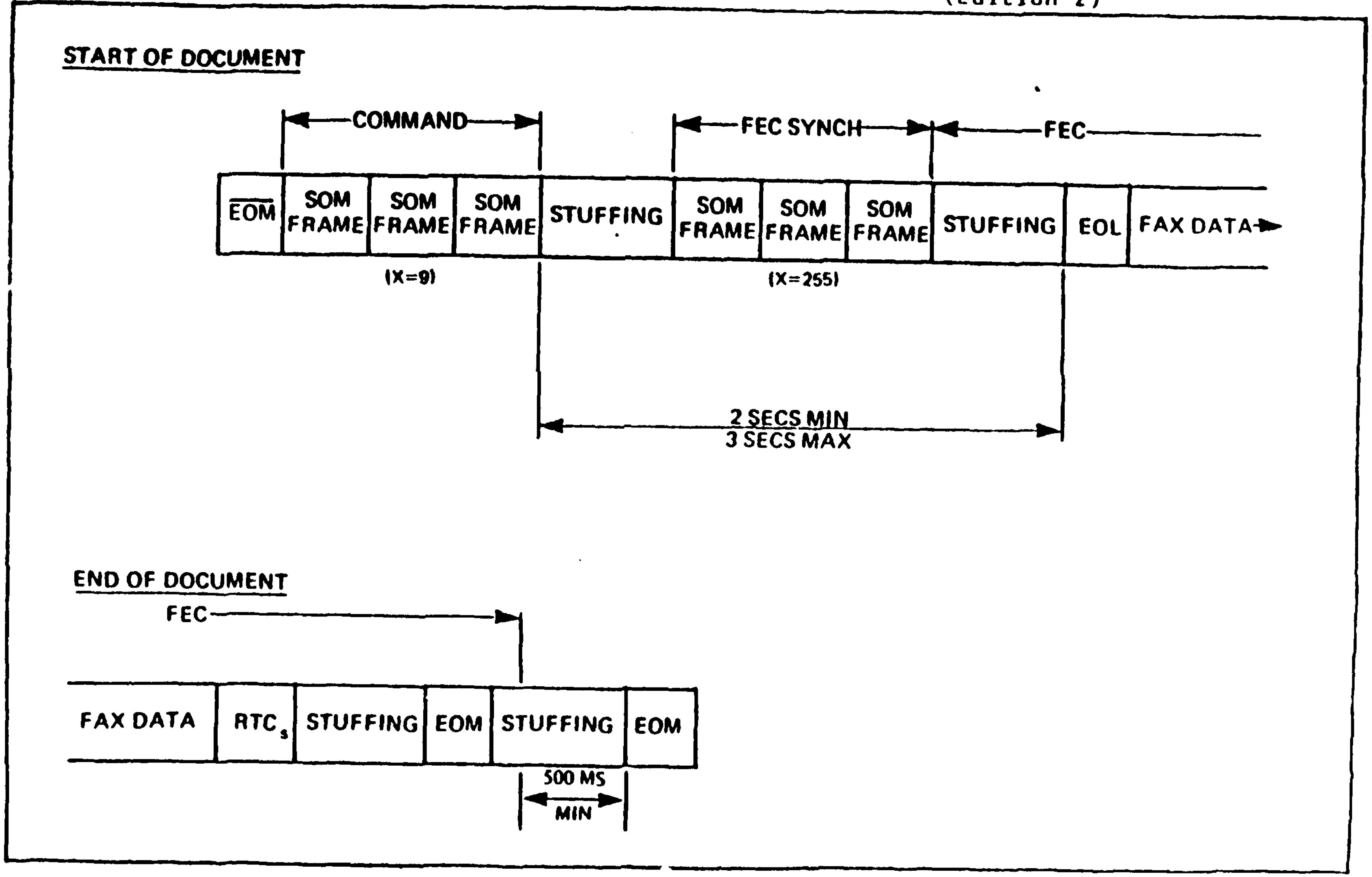


FIGURE 2 - SIGNAL TIMING, COMPRESSED MODE, FEC USED

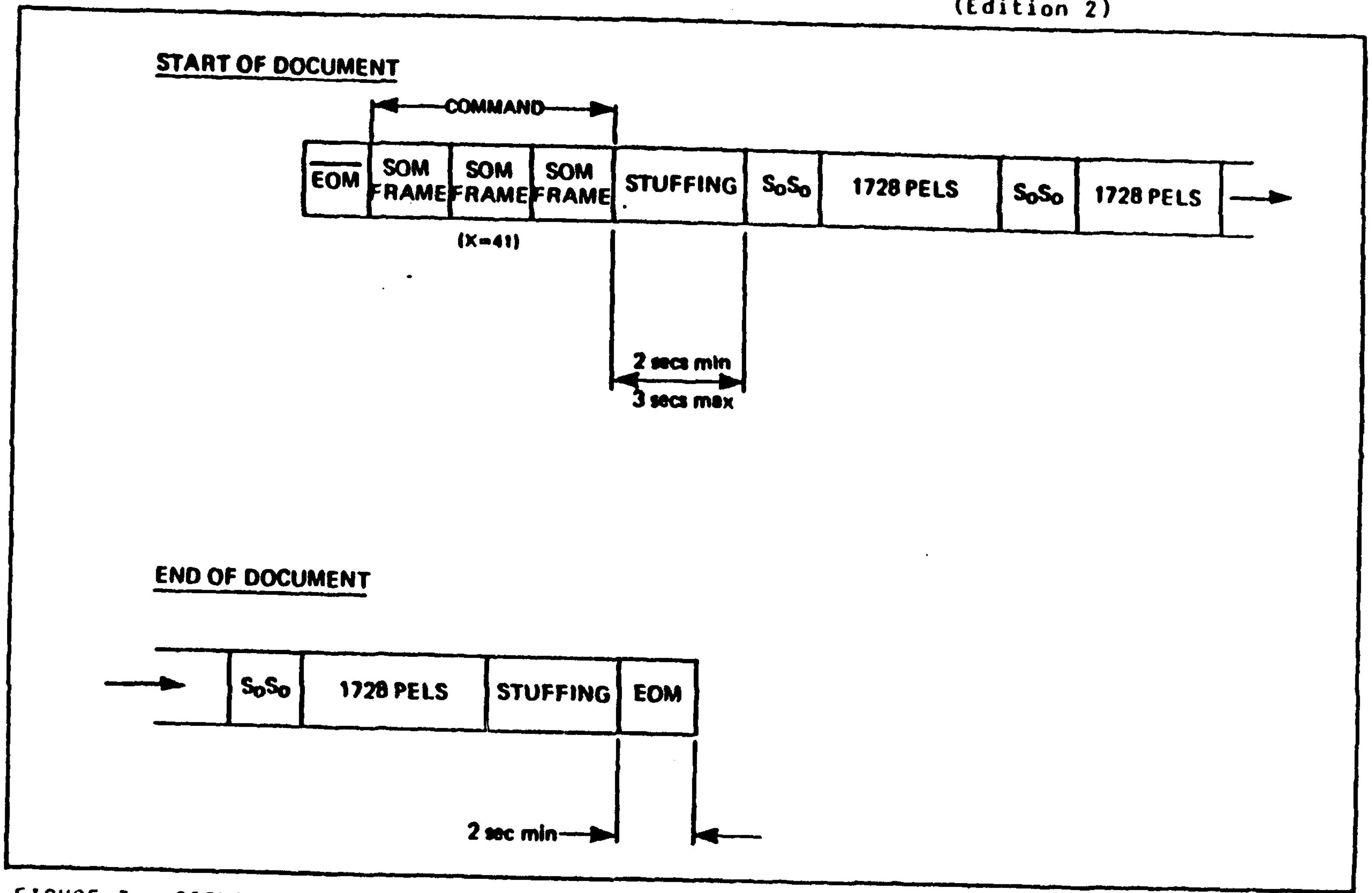


FIGURE 3 - SIGNAL TIMING, UNCOMPRESSED MODE

(f) During document transmission, if the receiver does not receive a line synchronization code or an EOM within a period of fifteen seconds, the receiver shall assume that the current transmission has terminated.

OPTIONAL IMAGE PARAMETERS

1. The following optional resolution modes have been identified:

(a) 7.7 lines per millimetre in the vertical direction and 1728 elements per scan line.

(b) 3.85 lines per millimetre in the vertical direction and 864 elements per scan line.

2. The signalling of these options is covered in Appendix 4, Protocols for Optional Modes.

HANDSHAKE PROTOCOLS

INTRODUCTION

1. In addition to the optional image parameters defined in Appendix 3, it is necessary to define handshake protocols for certain optional operating modes.

OPTIONAL IMAGE PARAMETERS

2. The signalling of the optional resolution modes is controlled by bits 4 and 3 of the COMMAND SOM as shown in Figure 1.

3. In Figure 1, black and white imaging is signalled by bits 2, 1, 0 as 001.

HANDSHAKE MODE

4. As illustrated in Annex A, Appendix 1, many communication configurations are possible. The NATO Mandatory Mode is possible in all configurations. However, configurations II to VI might require a response from the receiver. Figure 2 illustrates the bit assignments for the Response or Handshake SOM frame.

HANDSHAKE TIMING

5.

(a) In the Handshake mode, the sending station interrupts transmission after the Command SOM frames to listen for an acknowledgement. The FEC control SOM frames must be sent after receipt of acknwoledgement. Figures 3 and 4 illustrate the timing required to transmit an HSOM (with FEC enabled or disabled, respectively) when the receiving equipment's transmitter is in the standby mode.

Figures 6 and 7 illustrate the timing required to insert the HSOM within a line of FAX data if the receiving TDF is transmitting data.

(b) The signal format is the same as for NATO Mandatory Mode up to the end of the third Command SOM frame at which point the transmitter prepares to receive an acknowledgement.

(c) Figures 5 to 7 illustrate the timing required to insert an HSOM within a line of FAX data. An HSOM within a line of FAX data will not be transmitted with a preamble or an EOM. The level transmitted for "x" delay time, within the SOM frame, must be at a logic "1" level.

(d) If a satisfactory acknowledgement is received within fifteen seconds from the end of the first Command SOM frame, then the transmission of facsimile data, including the FEC control SOM frames, will commence no less than two seconds after the detection of an HSOM frame or no more than three seconds from the last HSOM frame.

(e) If an HSOM frame is not received within the defined period, the equipment shall return to a mode in which it is ready to respond to Command SOM frames. Similarly, if a facsimile line synchronization code has not been received within fifteen seconds of transmitting the final Response SOM frame, the receiver may return to the same mode.

(f) The end-of-document signal format is the same as for the NATO mandatory mode.

(g) When in full duplex and a transmission is being sent in the opposite direction, the response SOM should be inserted in the data stream at the end of a line (or a line pair) of data prior to fill and a line synchronization code.

COMMAND SOM FRAME

SI	So	X	So	SI

X Represents the number of transmitted bits (all 0s or all 1s) defined by the numerical value of the binary word assembled according to the required parameters:

MSB

7	6	5	4	3	2	1	0	
0	0				0	0	0	Unallocated
0	0				0	0	1	Black/White
0	0				0	1	0	Unallocated
0	0					1x		
0	0				1	1	1	
0	0		0	0				3.85 lines/mm x 864 pels/scanline
0	0		0	1				3.85 lines/mm x 1728 pels/scanline
0	0		1	0				7.7 lines/mm x 1728 pels/scanline
0	0		1	1				Unallocated
0	0	0						Compressed
0	0	1						Uncompressed

FIGURE 1 - X VALUE ALLOCATIONS FOR THE OPTIONAL COMMAND SOM FRAMES

RESPONSE SOM FRAME

S_1	So	X	So	S_1

X Represents the number of transmitted 1s defined by the numerical value of the binary word representing the required response:

MSB

7	6	5	4	3	2	1	0	
1	0	0	0	0	0	0	0	Unallocated
1	0	0	0	0	0	0	1	ACK-Equipment is ready to receive
1	0	0	0	0	0	1	0	NAK-Equipment is not ready
1	0	0	0	0	0	1	1	ILL-An illegal SOM was received
1	0	0	0	0	1	0	0	Available for future allocation for this STANAG or national unilateral use. See below for registered allocations.
				to				
1	0	1	1	1	1	1	1	

REGISTERED ALLOCATIONS

7	6	5	4	3	2	1	0	Alloted to	Purpose
1	0	0	0	1	1	1	0	US	National unilateral use
1	0	0	0	1	1	1	1	US	
1	0	0	1	0	0	0	0	US	
1	0	0	1	0	0	0	1	US	

NOTE: NATO agencies or nations will be allocated codes by the Electronics Section, International Staff, NATO HQ, Brussels on request subject to previous allocations. Such allocations are not subject to ratification.

FIGURE 2 - X VALUE ALLOCATIONS FOR OPTIONAL RESPONSE SOM FRAMES

B-4-4

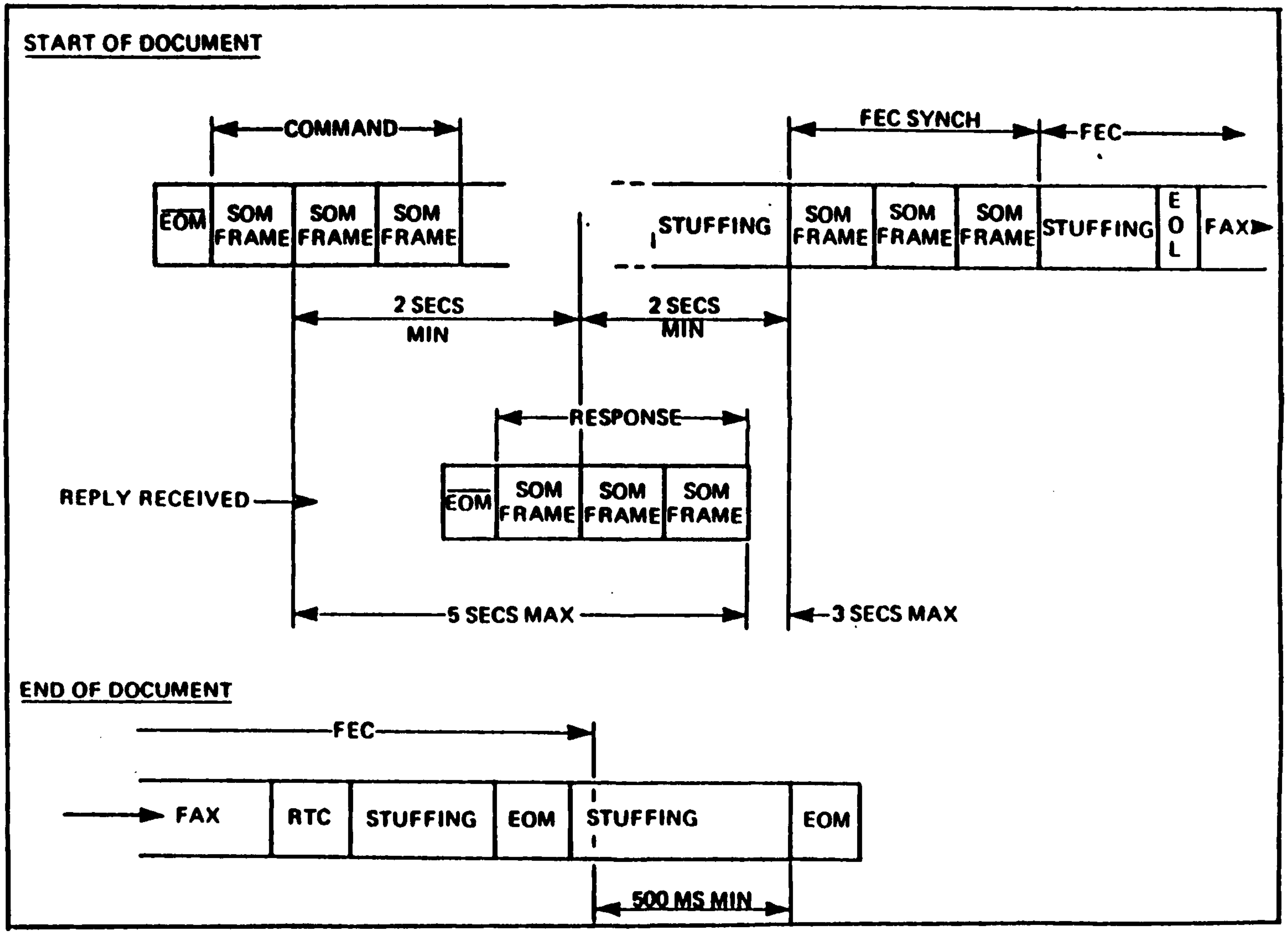


FIGURE 3 - TIMING, RESPONSE MODE, FEC USED

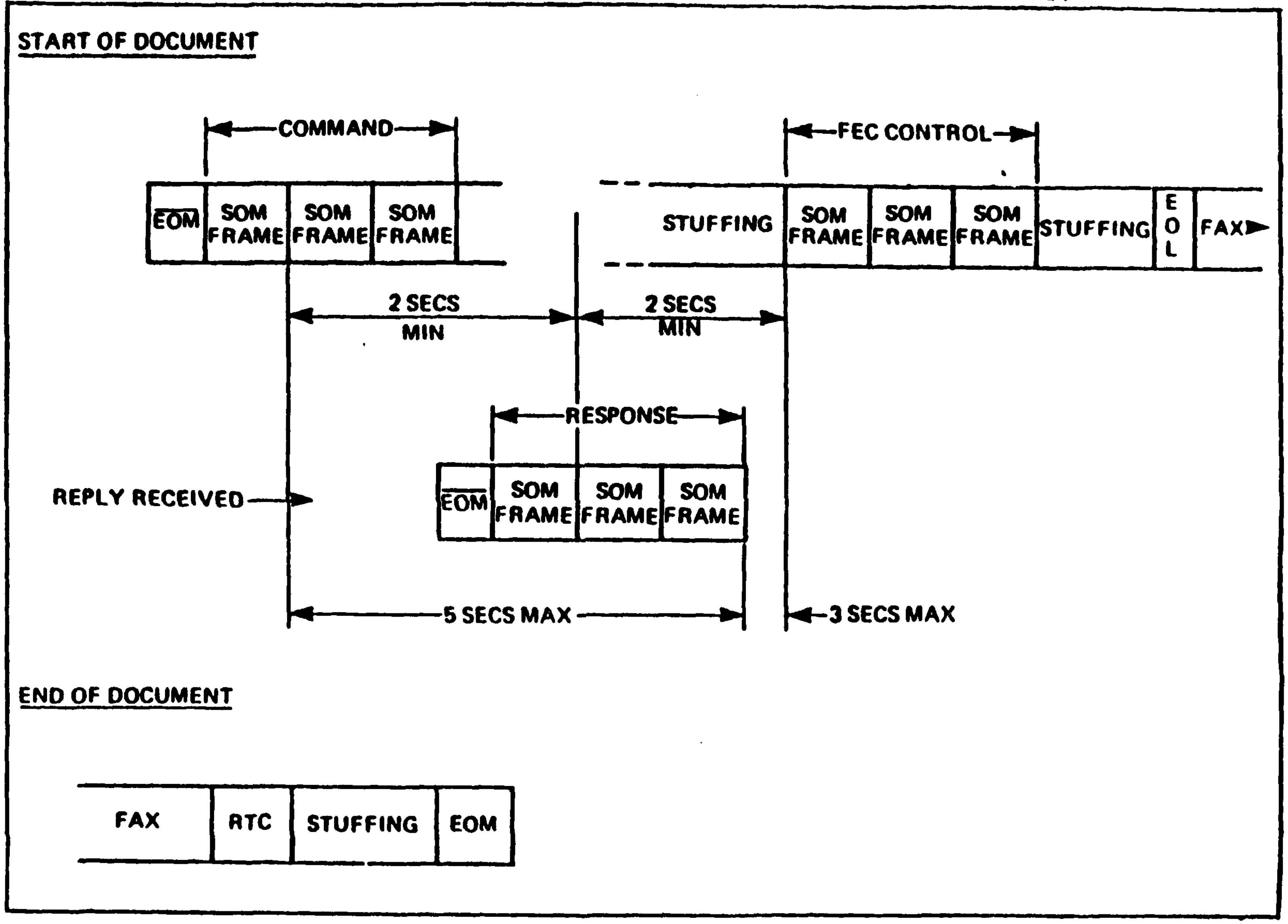


FIGURE 4 - TIMING, RESPONSE MODE, FEC NOT USED

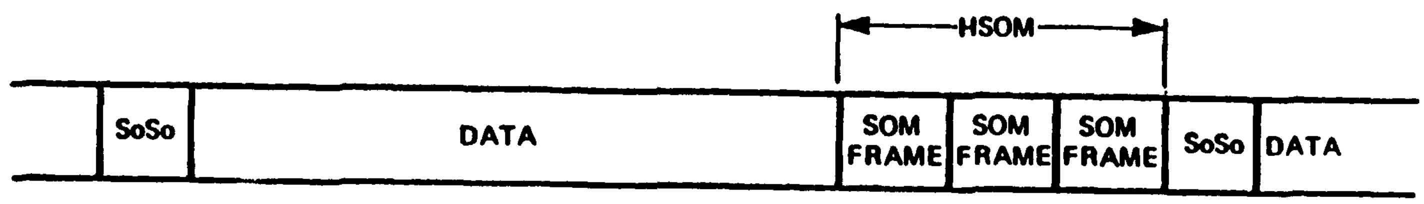


FIGURE 5 - TRANSMISSION OF THE HSOM WITHIN A LINE OF UNCOMPRESSED DATA

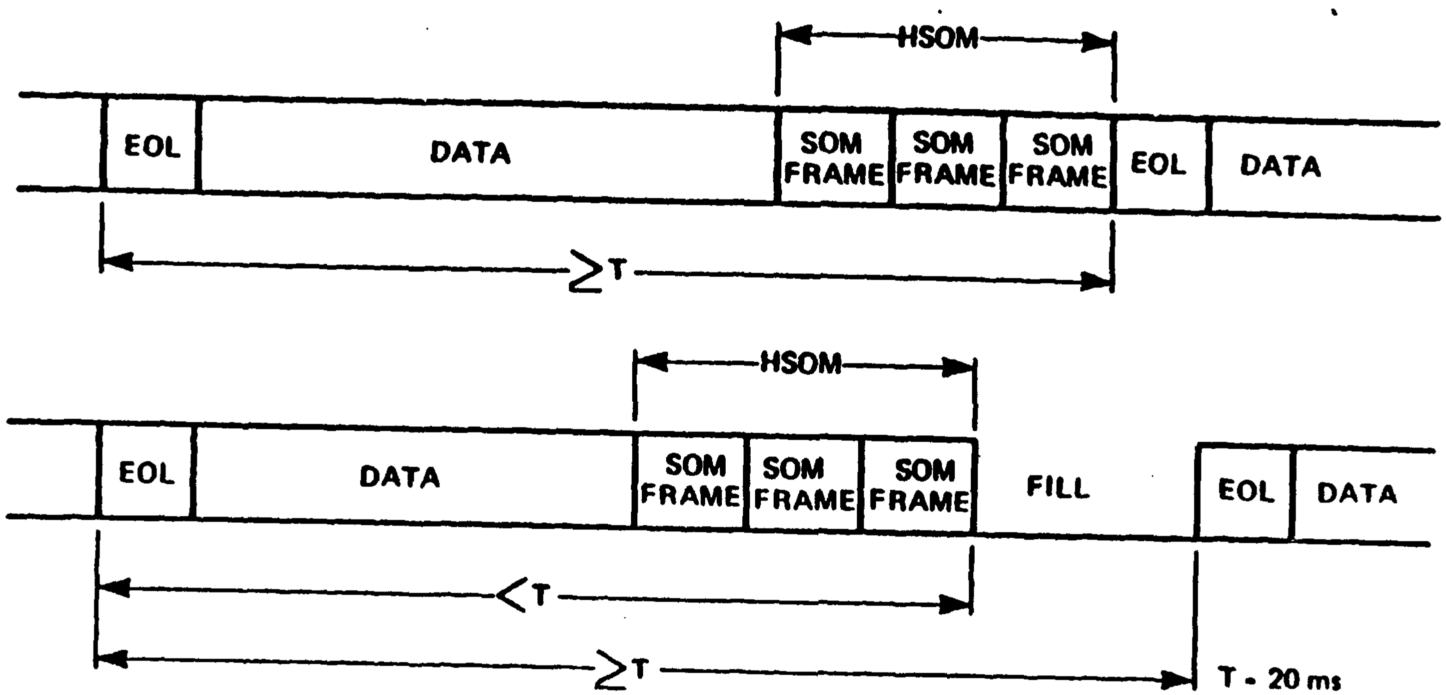


FIGURE 6 - TRANSMISSION OF HSOM WITHIN A LINE OF UNCOMPRESSED DATA

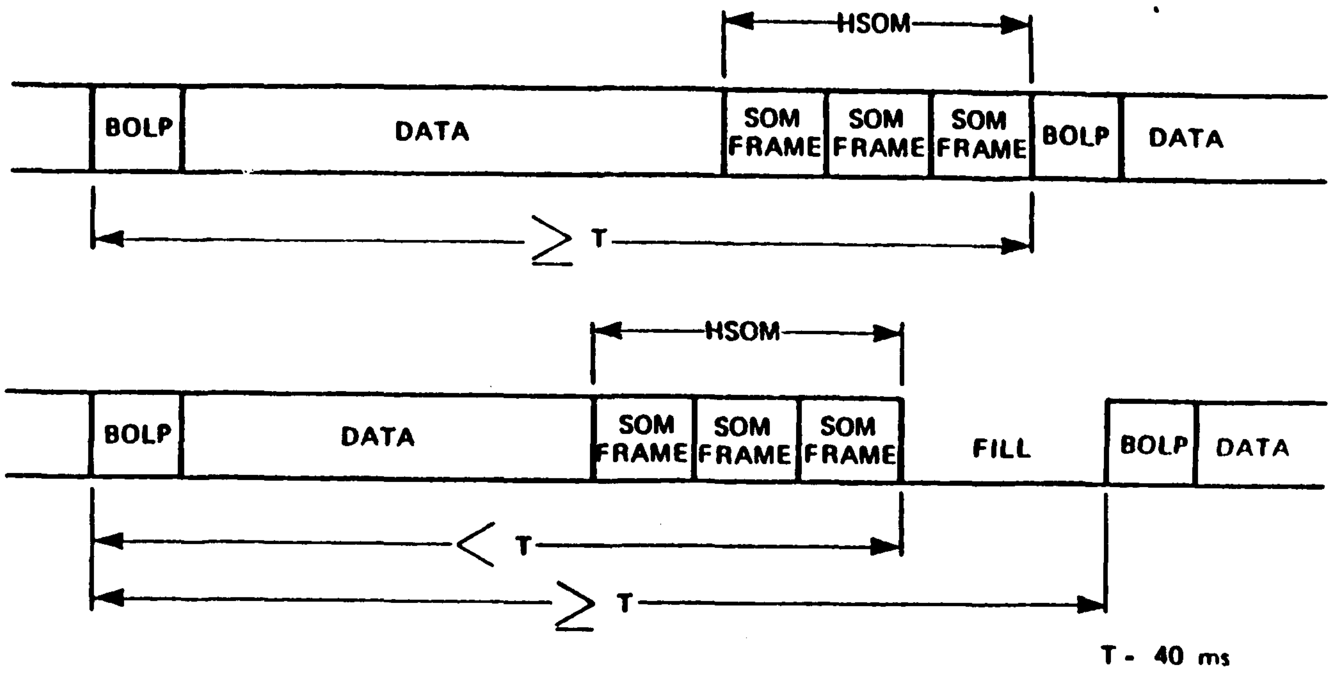


FIGURE 7 - TRANSMISSION OF THE HSOM WITHIN A LINE OF GRAY SCALE COMPRESSED DATA

EXTENDED PROTOCOLS

1. Some equipments may require the exchange of status and/or capabilities data in excess of those covered by Appendices 2 and 4.

2. Bits 0, 1 and 2 of the Command SOM are reserved for grey-scale definition in other types. Bit 6 is "0" in all SOM frame designators defined in Appendices 2 and 4. When set to "1" bit 6 will identify the use of an extended protocol involving the transmission of further SOM frames containing additional information. In all of these SOM frames bit 6 will be set to "1". The precise code allocations for such a protocol are not at present a concern of Annex B but shall be agreed upon for common use by NATO.

3. The existence of a protocol based upon extended SOM frames does not preclude national options based upon signalling methods not using PN code sequences.

TECHNICAL CHARACTERISTICS FOR INTEROPERABILITY OF NATO TYPE 2 TACTICAL DIGITAL FACSIMILE EQUIPMENT

GENERAL

1. This Annex establishes the mininum basic technical standards for interoperability of NATO Type 2 tactical digital facsimile equipment. It will apply to all equipment regardless of the types of circuits over which they will be required to operate. It is not concerned with the modems which may be required to interface with the transmission equipment.

2. Implementation of the standard will ensure that NATO Type 2 machines will be able to interoperate with each other in all mandatory modes. There may be optional secondary modes which may not be agreed to by all nations. Interoperation is considered to be satisfactory if the copy received on a machine of Nation X from a transmission of a machine of Nation Y is not significantly lower in quality than would be provided by a receiver of Nation Y's system under the same circumstances.

TRANSMISSION MODES

3. Operation includes broadcast, simplex, half-duplex and duplex as defined in Annex A. Possible equipment and communications configurations are also shown in Annex A, Appendix 1.

IMAGE PARAMETERS

4. All NATO Type 2 equipment shall be capable of interoperating to the following parameters:

(a) definition standards of 3.85 and 7.7 scan lines per mm in vertical direction;

(b) 1728 picture elements (PELs) along the scan line;

(c) definition standards of 2, 4 8 or 16 shades of grey for each picture element transmitted;

(d) a scanned line length of 215 mm;

(e) image proportions will be maintained within ± 1%;

(f) input documents up to 215 mm wide by 1000 mm(1) long shall be accepted. As a national option, input documents 230 mm wide may be accommodated although only 215 mm of the document will be transmitted.

---

(1) Documents up to 1000 mm long must be transmitted and received in one pass without interruption. The end of a document transmission signal "Return to Control" can be sent for any length up to 1000 mm long.

This is to satisfy the requirement to transmit a standard aerial photograph, 9" x 9" without having to trim the photograph;

(g) scanning shall be from lift to right and top to bottom.

NOTE: A definition standard of 3.85 scan lines per mm in vertical direction and two contrast levels, black and white, for NATO Type 1 interoperation shall be provided.

SCANNED LINE TRANSMISSION TIME

5. The minimum transmission time of any scanned line pair shall be 40 milliseconds for all compressed, grey scale modes and 20 milliseconds per second line for all black/white and uncompressed grey scale modes.

ELECTRICAL INTERFACE

6. Electrical characteristics of interfaces shall be as required by national standards.

DATA TRANSMISSION RATES

7. Equipment must be able to interoperate at 2.4 and 16 kilobits per second and at other rates between 1.2 and 16 kilobits per second as may be agreed to in NATO. The data transmission rate is selected by operators in accordance with the standard operating procedures for interoperation. The facsimile equipment will derive its clock rate from the communications equipment to which it is connected.

IMAGE DATA CODING

8. The choice of the following three forms of data coding shall be provided:

(a) uncompressed;

(b) compressed;

(c) compressed (as (b)) with forward error correction (FEC).

These coding schemes are fully described in Appendix 1.

9. The required mode is selected by the operator at the transmitting facsimile equipment. The transmitter will automatically, using the pre-message protocol, programme the receiving machine in the appropriate mode and coding form.

REQUIRED SIGNALS FOR INTEROPERABILITY

10. The signals listed below are mandatory. Other signals may be required by national procedures.

(a) Signals extracted from the V.24 Recommendation of the CCITT Orange Book:

(1) Signal Common Return (102);

(2) Transmitted Data (103);

(3) Received Data (104);

(4) Request to Send (105);

(5) Ready for Sending (106);

(6) Data Set Ready (107);

(7) Data Terminal Ready (108/2);

(8) Transmitter Signal Element Timing from DCE (114);

(9) Receiver Signal Element Timing from DCE (115).

(b) Loss of Facsimile Synchroni ation Signal:

(1) the receiver shall be capable of detecting loss of synchronization;

(2) at any time following detection of the first synchronization signal, the receiver shall declare a loss of synchronization, if a synchronization code has not been detected within a time-out period. This period shall be sufficiently long to preclude false declarations of synchronization;

(3) the signal indicating this loss shall be an "on" state, as defined by national electrical interface standards, applied to the Loss of Synchronization Interchange Circuit.

11. A protective ground is required.

SIGNALLING PROTOCOLS

12. The signalling protocol includes both the pre-message procedure and post-message procedure. Details of the protocols signals are in Appendix 2.

OPTIONS

13. In addition to the above mandatory parameters, the following options are defined:

(a) Optional Image Parameters - Appendix 3;

(b) Optional Signalling Protocols - Appendix 4;

(c) Extended Protocols - Appendix 5 to Annex B.

IMAGE DATA CODING SCHEMES FOR THE NATO MANDATORY MODES

INTRODUCTION

1. NATO Type 2 equipment will be capable of both grey scale and black/white operation. To interoperate with NATO Type 1 equipment, NATO Type 2 equipment will emulate the NATO Type 1 mandatory modes of black/white transmission.

BLACK/WHITE TRANSMISSION

2. For black/white transmission:

(a) 3.85 scan lines/mm (NATO Type 1 interoperation); and

(b) 7.7 scan lines/mm (high resolution, same as optional Type 1 mode).

3. The Image Data Coding Schemes as described in Appendix 1 to Annex B (for NATO Type 1 equipment) shall apply.

4. The signalling protocol as described in Appendix 2 shall apply.

GREY SCALE PREPROCESSING

5. Grey Scale - In addition to black/white operation, NATO Type 2 equipment shall be capable of transmitting and receiving documents in 4, 8 and 16 shades of grey. The normalized, grey density scale shall be as defined in Table 1.

6. The scanned dynamic range (D maximum/Step 16 - Paper White/Step 1) is selected and the linear distribution of steps between these two is determined by the fractional values of Table 1.

7. The recorded dynamic range (D maximum/Step 16 - Paper White/Step 1) is determined by the reprographic process capability. The distribution linear of steps over the dynamic range is determined by the fractional values of Table 1. Recorded grey shade values shall be in accordance with Table 2.

8. The separation of this specification for the scanner and recorder allows different dynamic range capability for each.

9. Gray-Coding - Grey scale shall be processed by initial conversion of each picture element of the scanned signal to 4 bit, Gray-coded image data representing each of the 16 shades of grey. A Gray-code (in accordance with Table 2) shall be used so that a minimum number of transitions occurs between adjacent grey levels. Gray-coding applies to all three transmission modes of paragraph 12.

10. Bit Plane Encoding - The data shall then be processed as bit planes. The Most Significant Bit (MSB) plane (1) contains the MSB (1) of each Gray-coded picture element (PEL). Similarly, Plane 2 contains bit 2 of each Gray-coded PEL, etc. Thus each plane, consisting of black and white PELs, can be treated as a black and white image.

11. For 16 grey shades, the four bit planes are passed directly to the transmission process. For 8 grey shades, bit plane 4 is discarded (by discarding bit 4) and the remaining 3 bit codes represent 8 grey shades (Table 2). Similarly, for 4 grey shades, plane 3 is discarded in addition to plane 4. The remaining 2 bit codes represent 4 grey shades (Table 2).

GREY SCALE TRANSMISSION

12. The encoder and decoder block diagrams (Figures 1 and 2) of Appendix 1 to Annex B apply. Three output modes shall be available:

(a) uncompressed facsimile data with line synchronization codes added;

(b) compressed facsimile data using a two-dimensional algorithm;

(c) compressed as in (b) with the addition of Forward Error Correction (FEC) using a BCH code and bit interleaving buffer.

13. It is necessary that the scheme selected for a given transmission be signalled to the receiver. This signalling protocol is described in Appendix 2.

14. Uncompressed - At data output A (Figure 1, Appendix 1 to Annex B), a document shall be transmitted PEL by PEL per bit-plane with logic 1 representing black. Each scan line of the output data shall consist of a synchronization code followed y 1728 PELs of the most significant bit-plane followed by the .28 PELs of the next most significant bit-planes in order. The synchronization code consists of two code sequences designated S_0, and are identicial to the codes utilized for NATO Type 1 equipment, uncompressed transmission.

Therefore, the scan line data format for 16 grey shades (uncompressed) is:

		Plane 1	Plane 2	Plane 3	Plane 4
S_0	S_0	1728 BITS	1728 BITS	1728 BITS	1728 BITS
		MSBP			LSBP

The scan line format for 8 grey shades (uncompressed) is:

		Plane 1	Plane 2	Plane 3
S_0	S_0	1728 BITS	1728 BITS	1728 BITS
		MSBP		

The scan line format for 4 grey shades (uncompressed) is:

		Plane 1	Plane 2
S_0	S_0	1728 BITS	1728 BITS
		MSBB	

MSBP Most Significant Bit Plane
LSBP Least Significant Bit Plane

Table 1. Normalized Grey Scale Shades

	Step Number	Normalized Density
Paper White	1	0.000
	2	0.067
	3	0.133
	4	0.200
	5	0.267
	6	0.333
	7	0.400
	8	0.467
	9	0.533
	10	0.600
	11	0.667
	12	0.733
	13	0.800
	14	0.867
	15	0.933
D maximum	16	1.000

Table 2. Gray-Codes for 4, 8 and 16 Grey Shades

16 Shades		8 Shades		4 Shades	
Steps	Gray Code	Table 1 Steps	Gray Code	Table 1 Steps	Gray Code
1	0000	1	000	1	00
Paper White 2	0001				
3	0011				
4	0010	4	001		
5	0110				
6	0111	6	011	6	01
7	0101				
8	0100	8	010		
9	1100				
10	1101	10	110		
11	1111				
12	1110	12	111	12	11
13	1010				
14	1011	14	101		
15	1001				
16	1000	16	100	16	10

Bits 1234 (MSB: bit 1, LSB: bit 4)　Bits 123 (MSB: bit 1)　Bits 12 (MSB: bit 1)

Note: MSB = Most Significant Bit
LSB = Least Significant Bit

15. Compressed - At data output B (Figure 1, Appendix 1 to Annex B), facsimile data is transmitted after compression by using a two-dimensional scheme as follows:

(a) Data:

(1) a line pair of data (see Figure 1) is composed of a series of variable length code words forming the bit-planes representing the first 864 picture elements of each of the two adjacent horizontal scan lines of the original document, (1728 total), followed by the second 864 elements of the two adjacent horizontal scan lines of the original document. Each half line pair of output data shall consist of the bit-planes in order (most significant bit-plane first), each bit-plane separated by a synchronization word, EOL. It is a unique code word that can never be found within a valid line pair of data. Therefore, re-synchronization after an error burst is possible: EOL format: 000000000001;

(2) each half line pair of output data shall be preceded by a three bit auto resolution code word (see paragraph 15(b));

(3) the relative placement of synchronization codes, auto resolution signalling bits, encoded data, EOL and fill is illustrated in Figures 1 and 2.

Note: 16 grey shade transmission is shown. For less grey shade transmission, the appropriate bit planes (and preceding EOL) are not present;

(4) the two adjacent scan lines of data shall be "wobbled" on a bit-plane by bit-plane basis prior to variable-length encoding by combining the spatially related data bits per bit-plane (Figure 3) in a wobble fashion according to the following:
(Note: L11, L12, L13, etc. represent the sequentially scanned bits derived from line N and L21, L22, L23, etc. represents the sequentially scanned bits derived from line N + 1.)

Combined Output: L11, L21, L22, L12, L13, L23, L24, L14, etc.

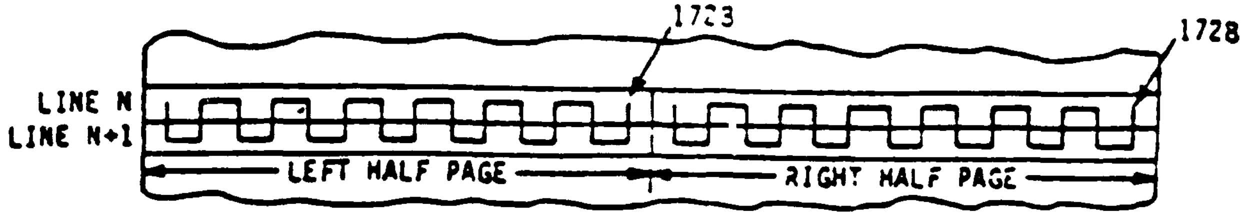


Figure 3. Bit plane wobble data format

(5) the purpose of this wobble pattern is to take advantage of both horizontal and vertical correlations of adjacent PELs. This leads to a higher compression than achievable with one dimensional coding which processes only one scan line at a time;

(6) each of the variable length code words represent a run-length of either all white or all black in a bit-plane. White and black runs alternate. In order to ensure that the receiver maintains black/white synchronization each of the bit-planes for each half of the DATA line pair will begin with a white run-length code word. If an actual half data line of a bit-plane begins with a black run, a white run-length of zero will be sent. Black or white run-lengths, up to a maximum length of one half scan line pair (1728 bits) are defined by the code words in Appendix 1 to Annex B, Table 1 (Terminating Codes) and Table 2 (Make-Up Codes) for each bit-plane representation of the image;

(7) each run-length is represented by either one Terminating Code Word or one Make-Up Code Word followed by a Terminating Code Word. Note: each bit-plane represents a black/white and four immages comprise a total grey shade image:

(a) run-lengths in the range of 0 to 63 PELs are encoded with their appropriate Terminating Code Word;

(b) run-lengths in the range of 64 to 1728 PELs are encoded first by the Make-Up Code Word representing the run-length which is equal to or shorter than that required. This is then followed by the Terminating Code Word representing the difference between the required run-length and the run-length represented by the Make-Up Code;

(b) Auto Resolution: Means shall be provided to implement a half (low) resolution function (on a selected bit-plane basis) to increase the achievable compression by taking advantage of the fact that not all regions of a grey scale image contain high resolution information. Lower order bit-planes have little effect on the perceived resolution and as a consequence may be transmitted at lower resolution in regions of slow intensity variations. Bit-plane activity is determined and low resolution operation is automatically implemented on a half scan line pair (bit-plane) basis when the number of transitions of a given bit-plane (Table 3) is less than 60.

NOTE: The number of transitions is not an issue of interoperability and a threshold of sixty is a suggested implementation number.

(1) Auto Resolution Algorithm - when half resolution processing is selected, a majority logic decision will take place for each bit-plane group of four bits (L11, L12, L21, L22, etc.) being read in prior to run-length encoding to create a single bit which represents the average of the four bits:

(a) transmitter: perform a majority logic decision such that if 3 or 4 bits are "black", substitute a black bit for the group of four. If zero, 1 or 2 bits are "black" substitute a white bit for the group of four;

(b) receiver: expand each "black" data bit or "white" data bit received into four identical bits prior to data recording;

Table 3. Bit-Plane vs. Auto Resolution Function

	Auto Resolution Algorithm		
Bit Plane	16 Grey Shades	8 Grey Shades	4 Grey Shades
1 (MSBP)	not invoked	not invoked	not invoked
2	automatic decision	automatic decision	automatic decision
3	automatic decision*	automatic decision*	discard
4 (LSBP)	low resolution always invoked	discard	discard

* If bit-plane 2 automatically has selected majority logic processing (for a half scan line pair) bit-plane 3 shall provide majority logic processing regardless of threshold test.

(2) Signalling of Auto Resolution Mode; auto resolution processing must be specified to the receiving unit on a half scan line pair basis by preceding each half scan line pair with one of the following 3 bit codes of Table 4.

Table 4. Auto Resolution Signalling Codes

16 Grey Shades		8 Grey Shades		4 Grey Shades	
Code	Meaning	Code	Meaning	Code	Meaning
110	HHHL	110	HHH	-	-
100	HHLL	100	HHL	100	HH
000	HLLL	000	HLL	000	HL

BP1

H = High Resolution
L = Low Resolution

If the first bit (as a consequence of majority logic decision) of a half scan line pair bit-plane is black, a white run-length of zero will be sent prior to coding the half line pair of that bit-plane.

(c) Beginning-of-Line Pair (BOLP); these code words precede each line pair of coded data (Figure 1) and are unique code words that can never be found within a valid half line pair of coded data. Therefore, resynchronization after an error burst is possible:
BOLP Format: 00000000000000010.

(d) Beginning-of-Intermediate (Half Line) Pair (BILP); these words precede each (right half page) half line pair of data (Figure 1) and are unique code words that can never be found within a valid half line pair of coded data. Therefore, resynchronization after an error burst is possible:
BILP Format: 00000000000000011.

(e) Fill; a pause may be placed in the message flow by transmitting FILL. FILL may be inserted between a line pair of DATA and a BOLP but never within the bit-planes. FILL must be added to ensure that each line pair of DATA, FILL, BOLP and handshake SOM (when set) exceeds the minimum transmission time of a total scan line pair established as 40 milliseconds (Figure 1). The maximum length for a single line pair of FILL is 5 seconds. After this the receiver may

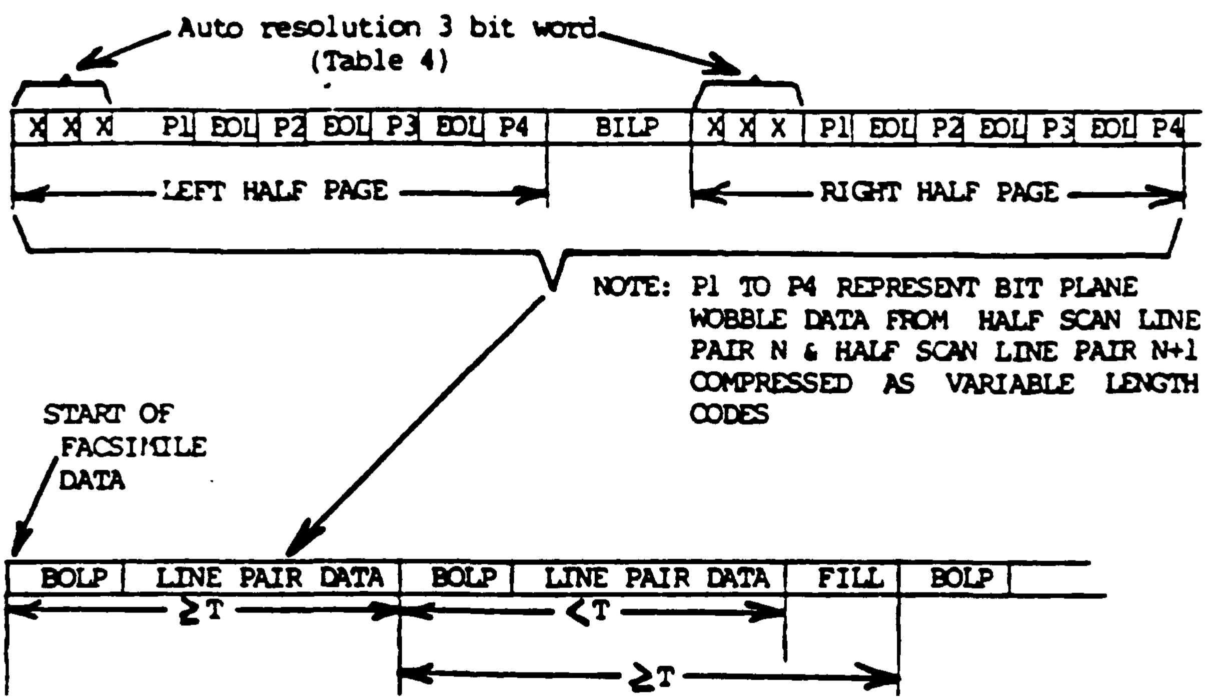
disconnect; FILL FORMAT: Variable-length strings of 0's

(f) Return to Control (RTC); the end of the document transmission is indicated by sending a minimum of two RTCs. Each RTC shall consist of six consecutive EOLs. Following the RTC signals, the transmitter will send the post-message commands.

RTC Format: 000000000001 ____________ 000000000001
EOL 1 EOL 6

16. Compressed with FEC. Since each bit-plane of a grey scale image is in itself a black and white image, the channel-coder, bit interleaving buffer and synchronization of items 7 through 12 of Appendix 1 to Annex B applies.

APPENDIX 1 to
ANNEX C to
STANAG 5000
(Edition 2)



NOTE: T = MINIMUM TRANSMISSION TIME OF A TOTAL SCAN LINE PAIR
BILP = BEGINNING OF INTERMEDIATE LINE PAIR
BOLP = BEGINNING OF LINE PAIR

Figure 1. Example for an encoded scan line pair of 16 grey shades starting at the beginning of a page

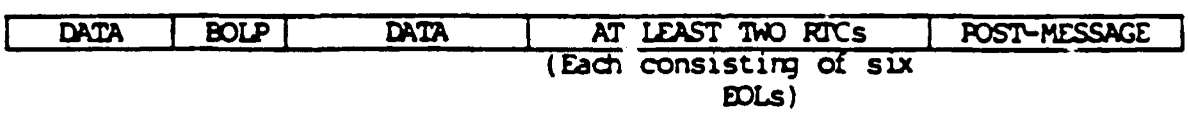


Figure 2. Example for an encoded scan line pair showing the last scan line pair of a page

SIGNALLING PROTOCOL FOR THE NATO MANDATORY MODES

INTRODUCTION

1. The selection of the parameters used for each transmission is signalled to the receiver using Start of Message (SOM) frames and the termination of the facsimile transmission is signalled by an End of Message (EOM) sequence.

2. The protocol signal structure is identical to NATO Type 1 equipment and has been specifically designed to provide extremely high assurance of correct receiver operation (automatic start, mode setup and automatic stop) in error environments as high as 10^{-2} bit error rate (BER). This means that a return acknowledge is not necessary for the mandatory mode which simplifies operation.

3. The design of the SOM allows for non-mandatory or alternative, operation modes and is covered in Appendix 3.

PROTOCOL SIGNAL DESCRIPTION

4. Synchronization Code Words. The synchronization code words to be used for NATO Type 2 equipment are identical to the words used for NATO Type 1 equipment. A definition of these words and their characteristics is described in paragraph 4 of Appendix 2 to Annex B.

5. Start of Message (SOM). Each SOM frame consists of two pairs of synchronization code words S_1/S_0, separated by an interval.

SOM frame format $\boxed{S_1 \mid S_0}$ $\longleftarrow$ x clock periods $\boxed{S_0 \mid S_1}$

6. The mode is indicated by the number of clock periods (X) between the two pairs of synchronization code words. The 18 values of X to be denoted the mandatory interoperability modes are shown in Table 1 along with the corresponding 8 bit binary designators.

7. The number of clock periods (X) transmitted during the interval between the two pairs of code words indicates the operating mode. The data bit corresponding to each of the clock periods shall be logic ones. The SOM frame is transmitted three

times but detection of any one frame is sufficient. Use of these signals is described in paragraph 9, Signalling Sequence and Timing. Values of X for optional modes are given in Appendix 4, Protocols for Optional Modes.

8. End of Message (EOM). EOM consists of at least 16 S_1 code words transmitted in sequence. When four consecutive S_1 code words have been detected, EOM is declared. This procedure is identicial to NATO Type 1 equipments.

SIGNALLING SEQUENCE AND TIMING

9. The sequence and timing for the compressed mode with and without FEC and the uncompressed mode is identical to paragraph 7 through 9 of Appendix 2 to Annex B.

APPENDIX 2 to
ANNEX C to
STANAG 5000
(Edition 2)

TABLE 1 VALUES OF X FOR NATO MANDATORY INTEROPERABILITY MODES

SOM TYPE	MODE INDICATED			NUMBER OF CLOCK PERIODS (X)	BINARY DESIGNATOR *							
					7	6	5	4	3	2	1	0
Command	Compressed	7.7 ipmm feed resolution	16 Shades	20	0	0	0	1	0	1	0	0
			8 Shades	19	0	0	0	1	0	0	1	1
			4 Shades	18	0	0	0	1	0	0	1	0
			B/W	17	0	0	0	1	0	0	0	1
		3.85 ipmm feed resolution	16 Shades	12	0	0	0	0	1	1	0	0
			8 Shades	11	0	0	0	0	1	0	1	1
			4 Shades	10	0	0	0	0	1	0	1	0
			B/W	9	0	0	0	0	1	0	0	1
	Uncompressed	7.7 ipmm feed resolution	16 Shades	52	0	0	1	1	0	1	0	0
			8 Shades	51	0	0	1	1	0	0	1	1
			4 Shades	50	0	0	1	1	0	0	1	0
			B/W	49	0	0	1	1	0	0	0	1
		3.85 ipmm feed resolution	16 Shades	44	0	0	1	0	1	1	0	0
			8 Shades	43	0	0	1	0	1	0	1	1
			4 Shades	42	0	0	1	0	1	0	1	0
			B/W	41	0	0	1	0	1	0	0	1
FEC Control	FEC Used			255	1	1	1	1	1	1	1	1
	FEC Not Used			254	1	1	1	1	1	1	1	0

* NATO Type 1 modes

OPTIONAL IMAGE PARAMETERS

1. Optional image modes are: 3.85 lines per mm in the vertical direction and 864 elements per scan line, for 2, 4, 8 and 16 grey shades.

2. Image data coding of these optional modes is covered in Appendix 1.

NOTE: The maximum number of PELs per half line pair in these modes is 864 elements.

3. The signalling of these optional modes is covered in Appendix 4, Protocols for Optional Modes.

PROTOCOLS FOR OTPIONAL MODES

INTRODUCITON

1. In addition to the optional image parameters defined in Appendix 3, it is necessary to identify certain optional operating modes:

(a) handshake mode;

(b) extended protocol.

OPTIONAL IMAGE PARAMETERS

2. The signalling of the optional resolution modes is controlled by bits 3 and 4 of the COMMAND SOM as shown in Figure 1.

HANDSHAKE MODE

3. The handshake mode protocol is identical to paragraph 5 of Appendix 4 to Annex B.

EXTENDED PROTOCOLS

4. The procedure for extended protocols is described in Appendix 5 to Annex B.

COMMAND SOM FRAME

S1	S0	X	S0	S1

X REPRESENTS THE NUMBER OF TRANSMITTED BITS (ALL 0s OR ALL 1s) DEFINED BY THE NUMERICAL VALUE OF THE BINARY WORD ASSEMBLED ACCORDING TO THE REQUIRED PARAMETERS:

MSB

7	6	5	4	3	2	1	0	
0	0				0	0	0	UNALLOCATED
0	0				0	0	1	BLACK/WHITE (MANDATORY)
0	0				0	1	0	4 SHADES (MANDATORY)
0	0				0	1	1	8 SHADES (MANDATORY)
0	0				1	0	0	16 SHADES (MANDATORY)
					1	0 TO 1	1 TO 1	UNALLOCATED
					1			
0	0		0	0				3.85 LINES/MM x 864 PELS/SCAN LINE (OPTIONAL)
0	0		0	1				3.85 LINES/MM x 1728 PELS/SCAN LINE (MANDATORY)
0	0		1	0				7.7 LINES/MM x 1728 PELS/SCAN LINE (MANDATORY)
0	0		1	1				UNALLOCATED
0	0	0						COMPRESSED
0	0	1						UNCOMPRESSED

Figure 1. X value allocation for the optional command SOM frames